

Trends in Water Quality in Lake Erie Tributaries, 1975-2004



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Outline

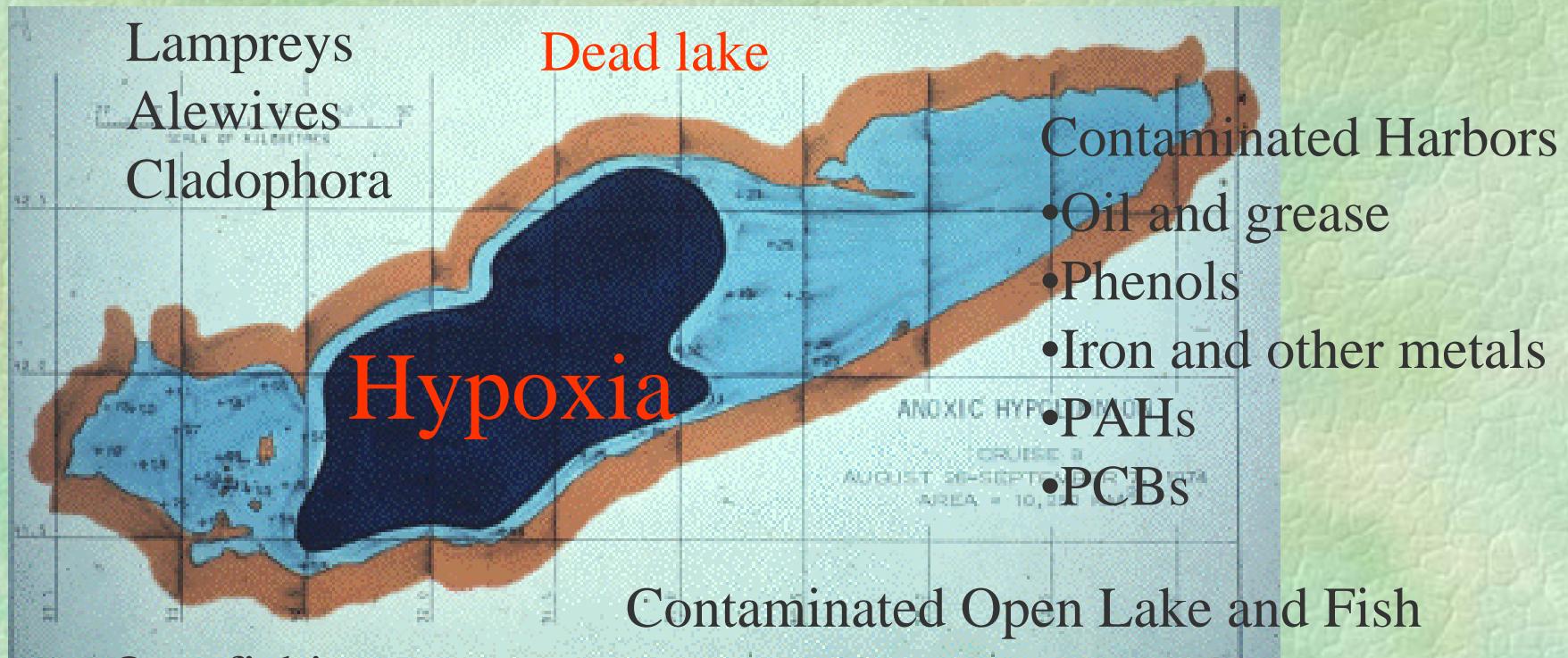
- ❖ The “death” and rehabilitation of Lake Erie
- ❖ Trends in nutrient loads
- ❖ Causes?

Cuyahoga River, 1952

Lake Erie is Dead!



What's wrong with Lake Erie?



Strategy for reducing hypoxia

❖ Reduce phosphorus

- Sewage Treatment Plant upgrades
- Phosphorus detergent ban
- Non-point source programs, especially aimed at agriculture
 - Nutrient management
 - Reduced tillage

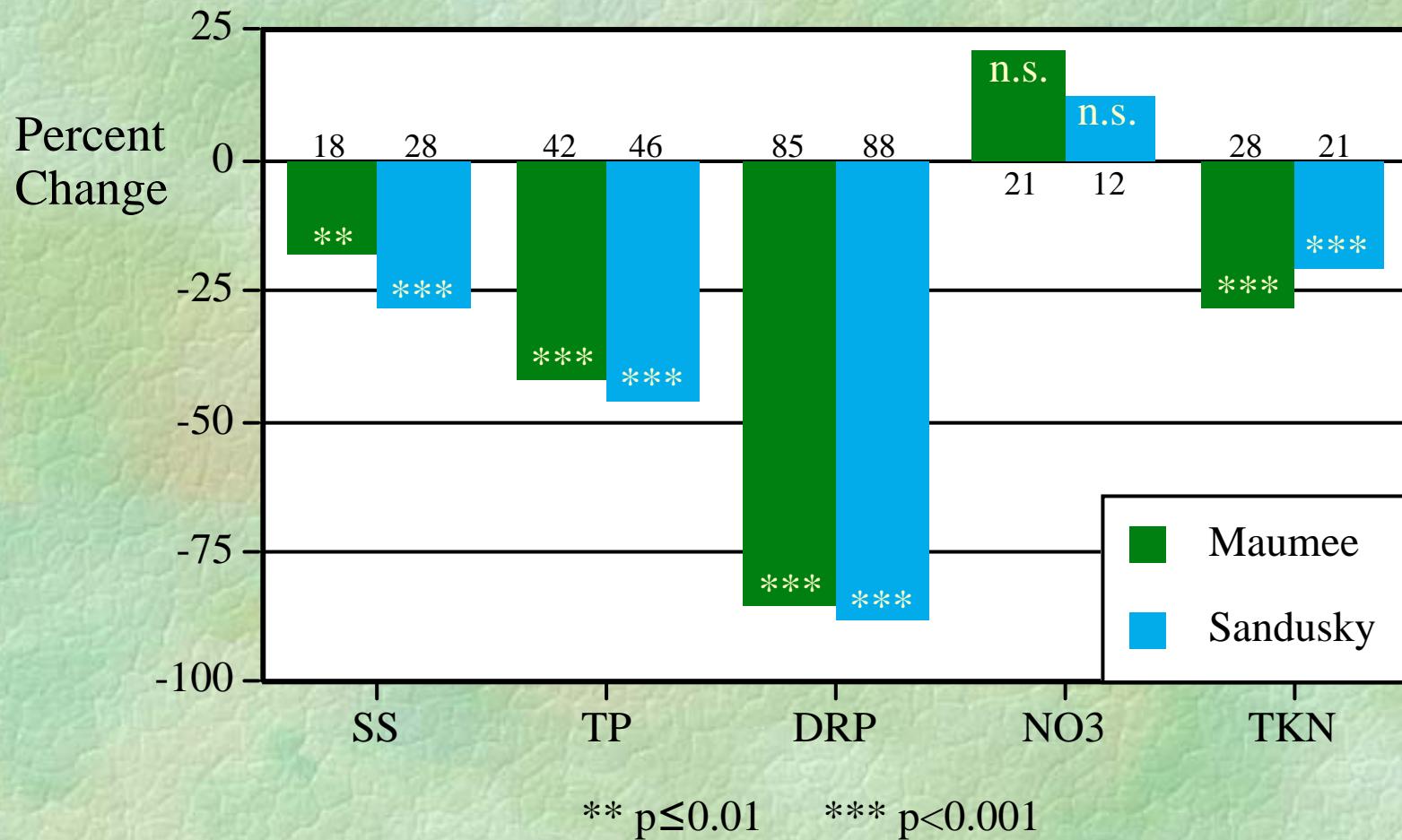
Tributary Loading Studies

❖ Army Corps Wastewater Management Study

❖ Heidelberg Tributary Sampling Program

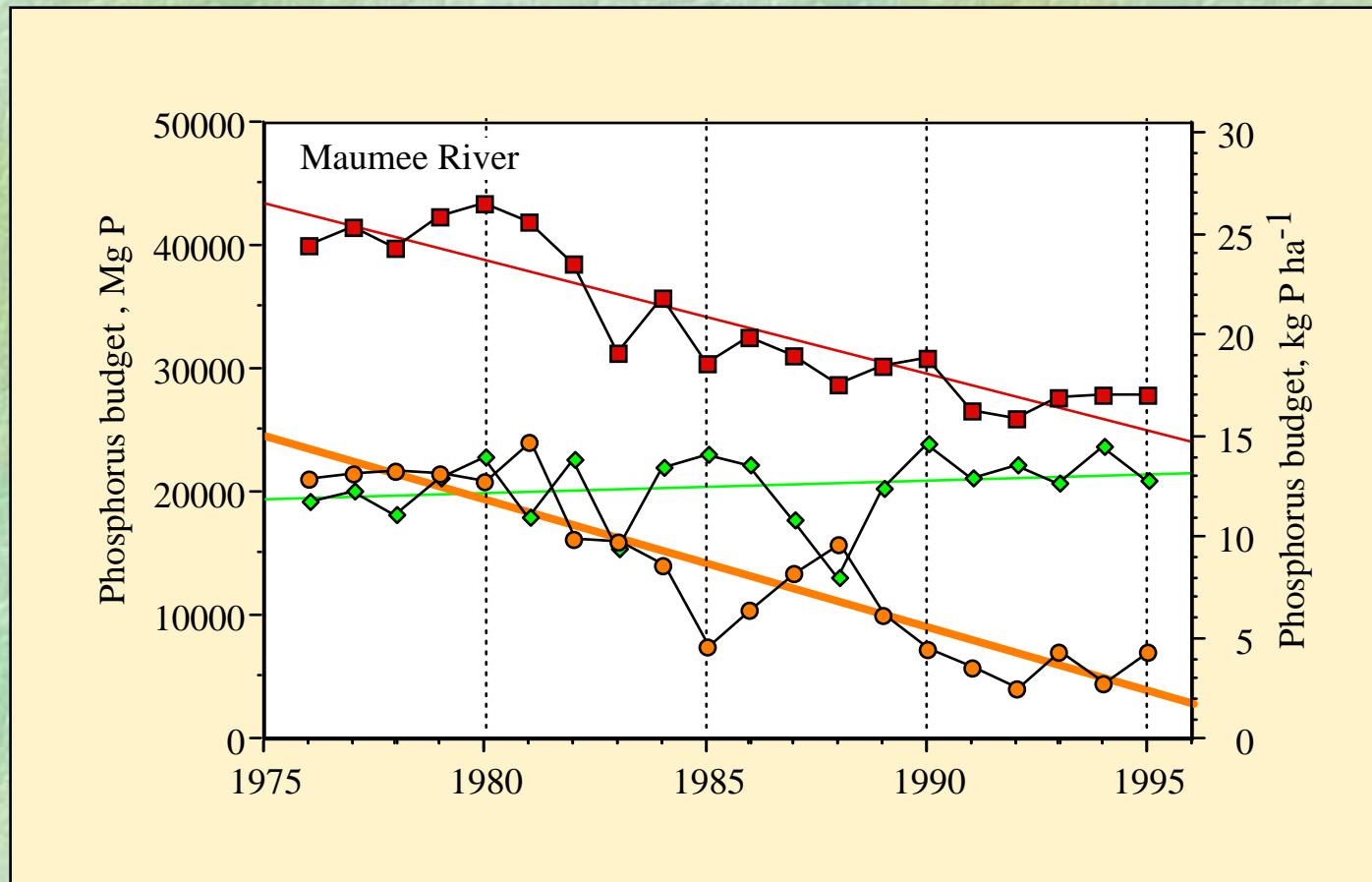
- Major Lake Erie Tribs
 - Sandusky 1974
 - Maumee 1975
 - Cuyahoga 1982
 - Raisin 1982
 - Grand 1986
- Autosamplers at “integrator” stations, 3 samples/day
- USDA-LEASEQ Trend Analysis 1975-1995 (Mau, Sand)
- USDA-CEAP Trend Analysis 1975-2004

Trends in Water Quality, 1975-1995



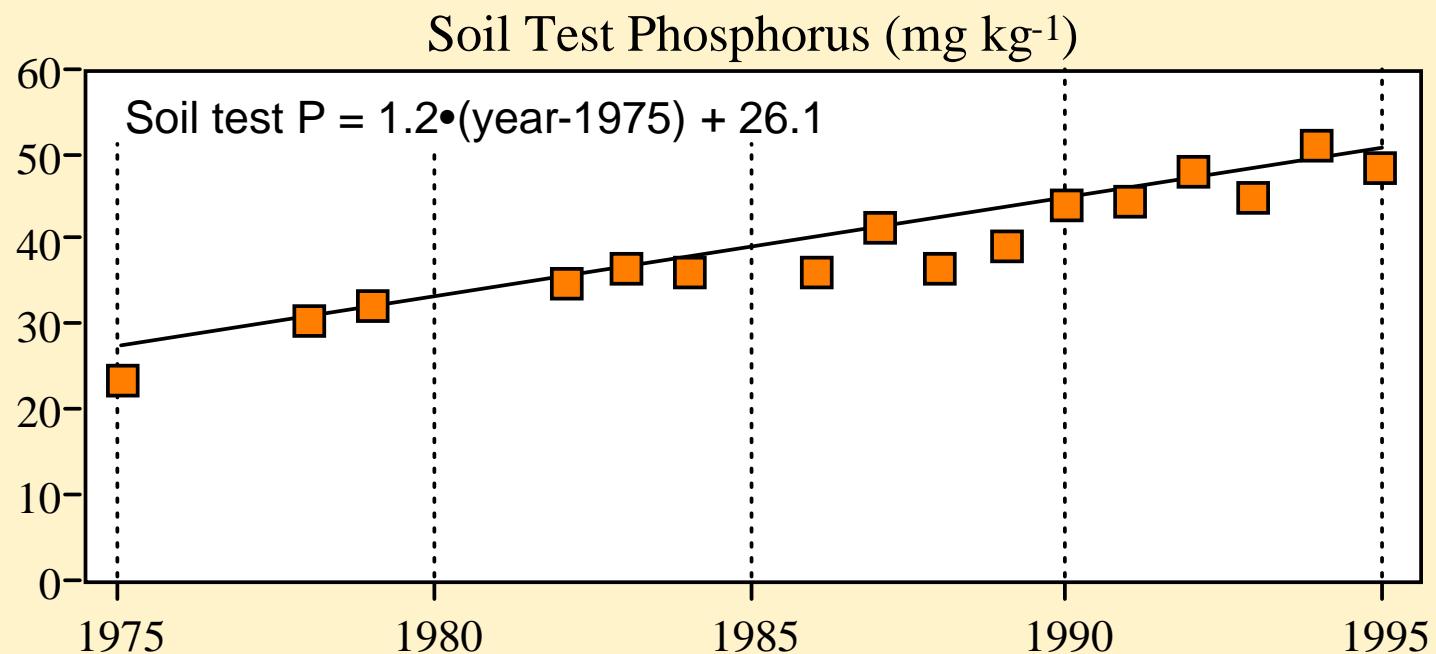
Trends in phosphorus mass balance

...substantial decrease, but always input>output



Trends in soil fertility

...nearly doubled between 1975 and 1995



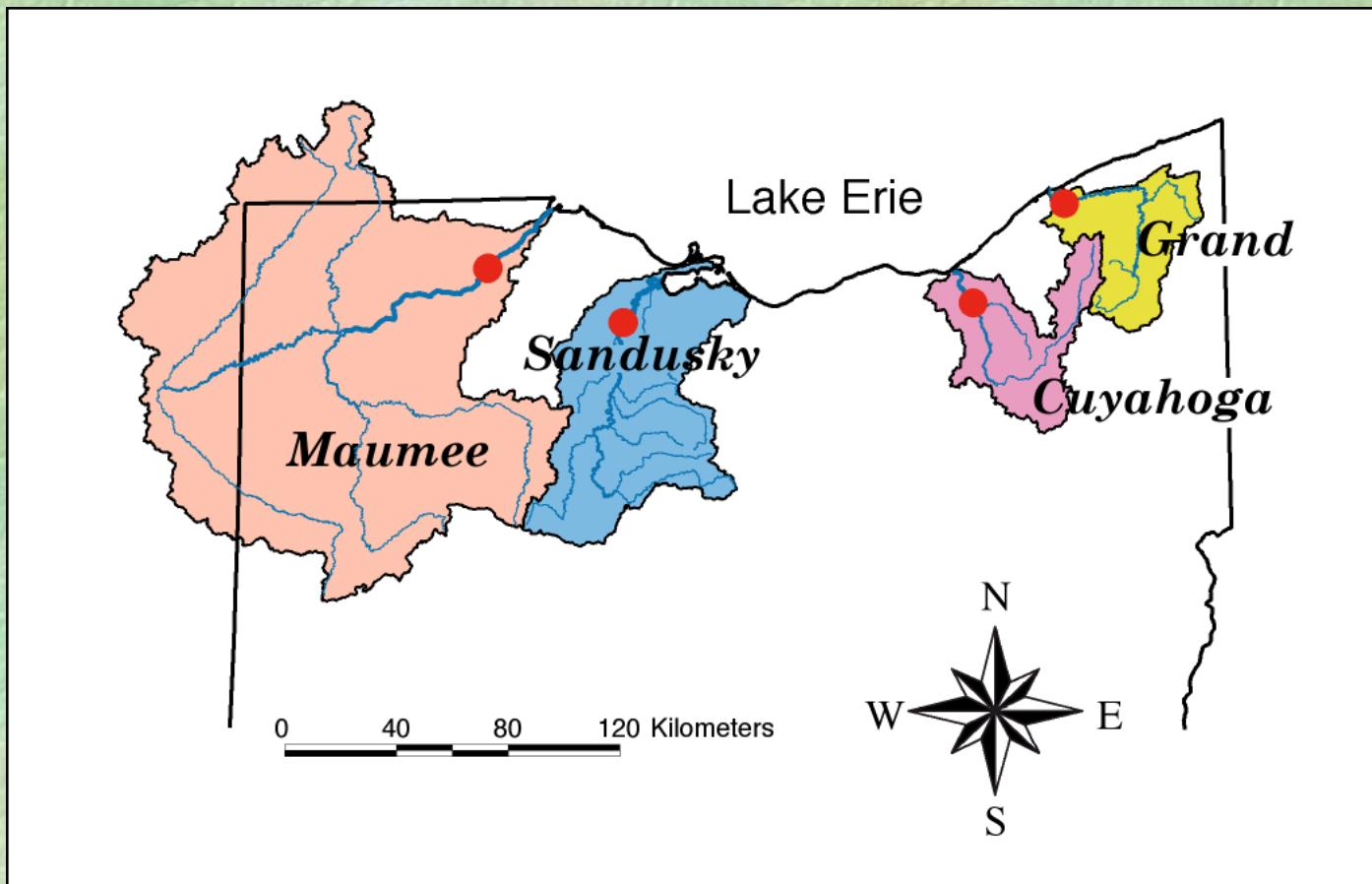
LEASEQ Conclusions

- ❖ Water quality trends are toward improved conditions (except nitrate)
- ❖ Water quality trends result from intentional changes in use of the land
- ❖ A major victory for environmental science and management

Trends 1995-2004:

- ❖ How do trends in the last 10 years compare with trends in the previous 20 years?
- ❖ Also extend analysis to Cuyahoga and Grand

Station Locations



Trends in Water Quality, 1975-2004

❖ Methods: Formal Analysis

- Adjust concentrations for flow effects, using LOWESS smoother
- Analyze trend in flow-corrected, log-transformed concentrations using **ANCOVA-based two slope model**
- $\log(c) = f_n[\log(q), t, \sin(2\pi t), \cos(2\pi t), \text{PrePost}, \text{PrePost} \cdot t]$
- Results expressed as % change over **10 years**

❖ Today: LOWESS smooths of unmodified daily flows and daily loads (bin width 20%)

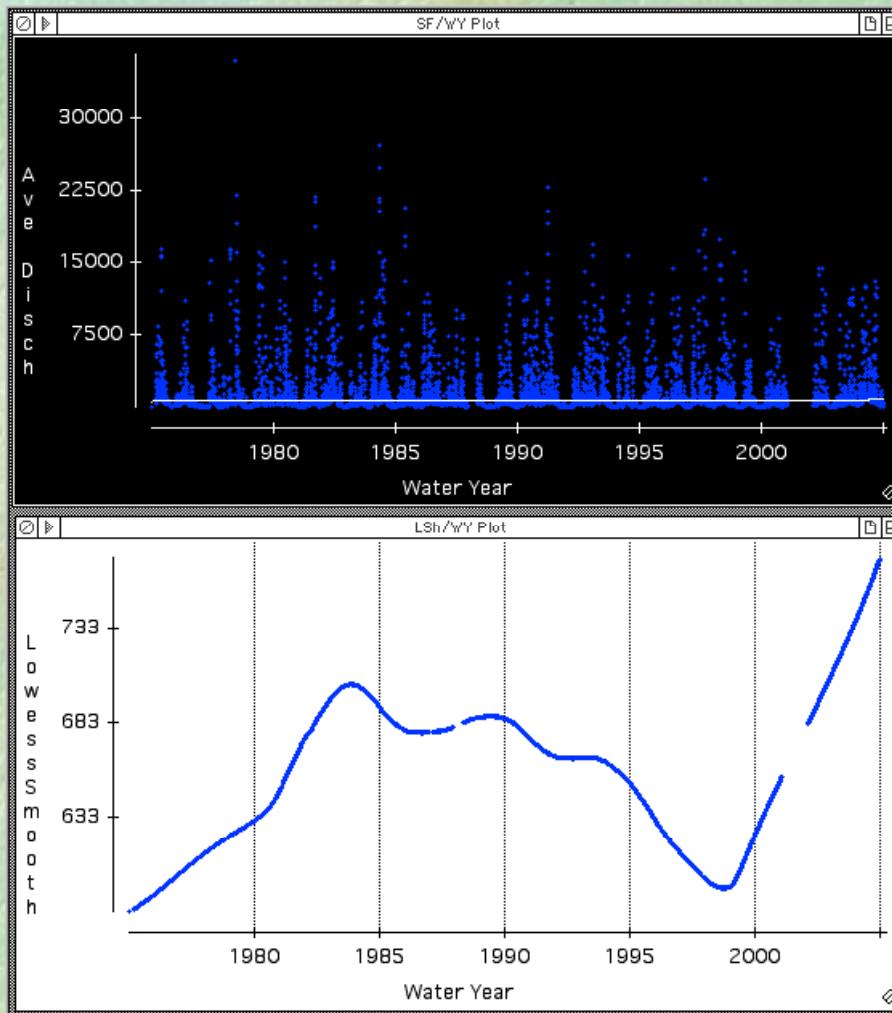
❖ LOWESS: LOcally WEighted Scatterplot Smooth

I. Loads vs. Concentrations, Sandusky

❖ Goals

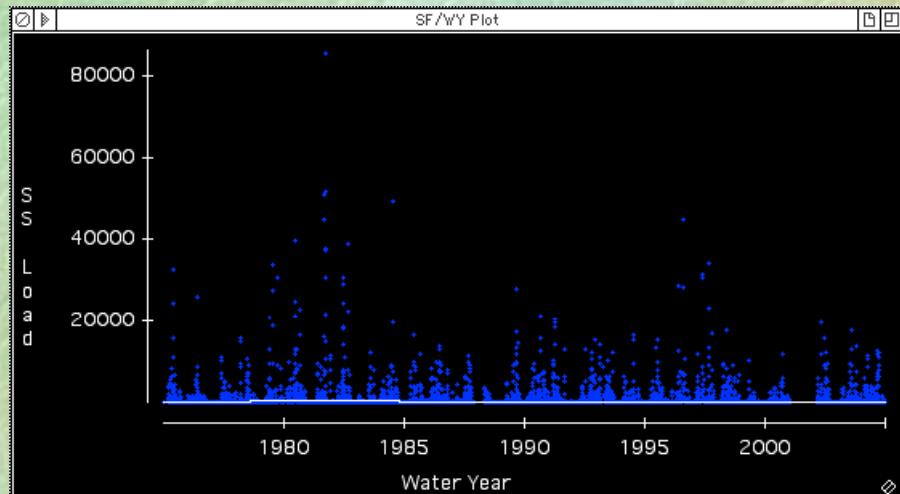
- Illustrate similarities/differences in trends for loads as opposed to concentrations
- Illustrate magnitude of trends relative to day-to-day fluctuations
- Avoid trying to show you 100+ different trend graphs!

Discharge

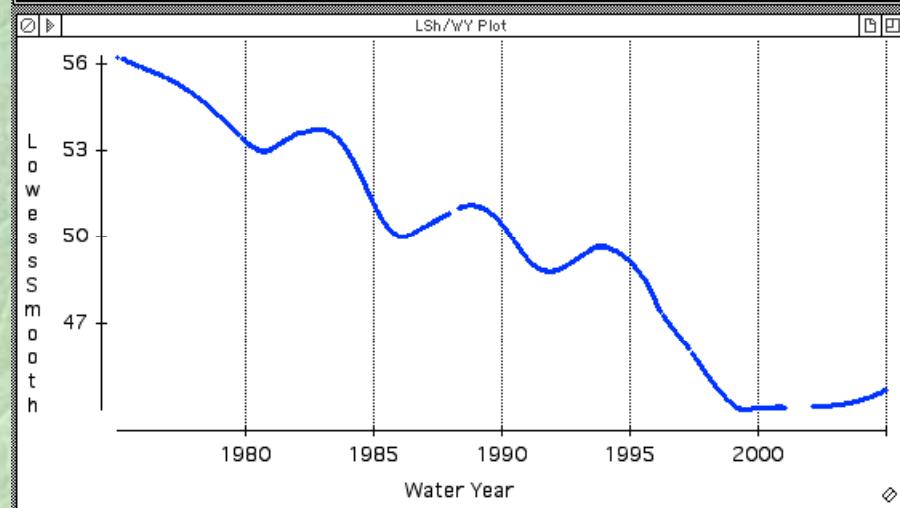
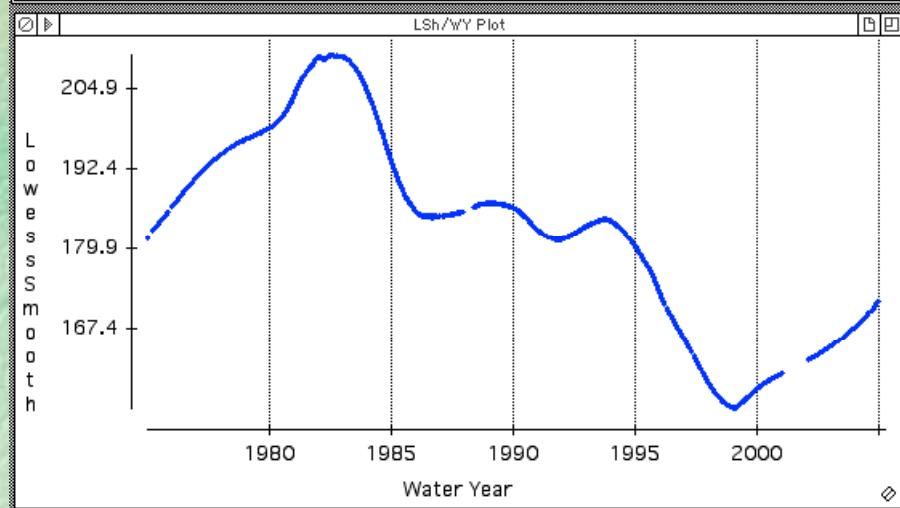
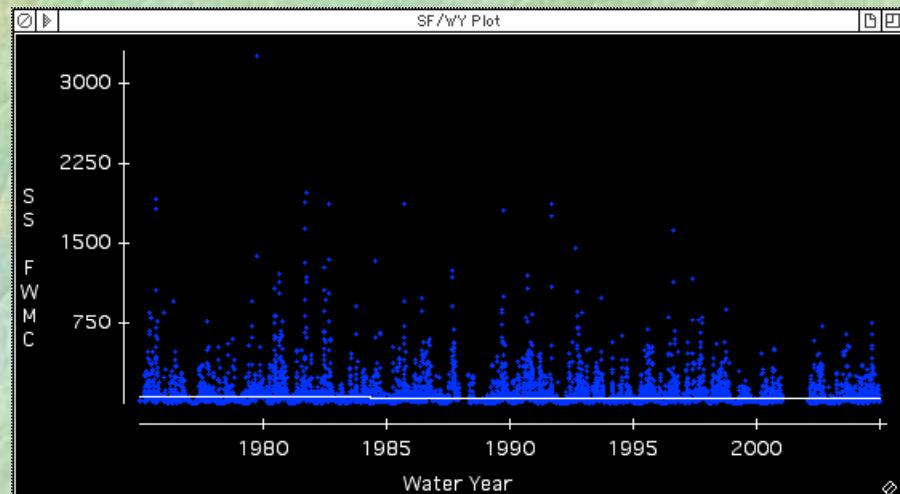


Suspended Sediment

Loads

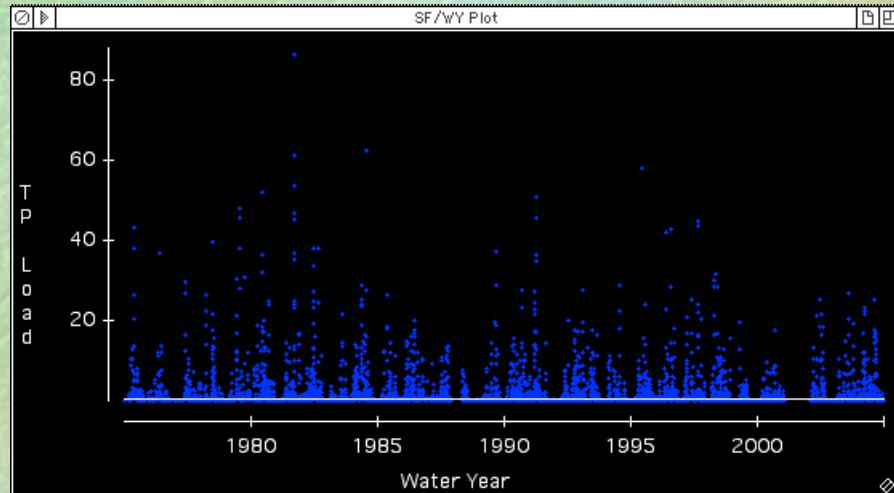


Concentrations

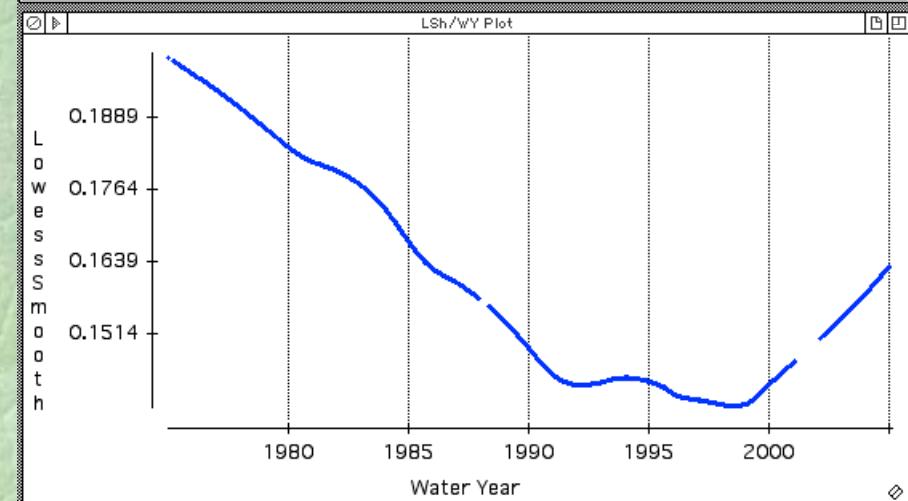
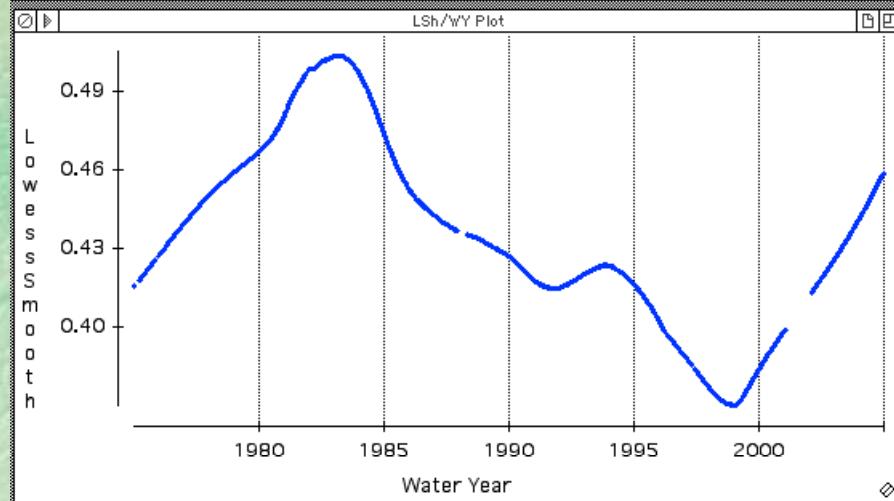
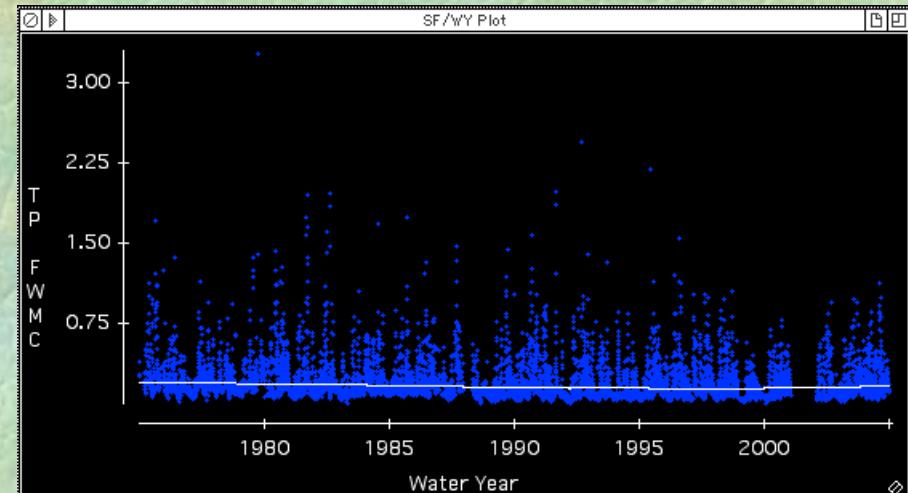


Total Phosphorus

Loads

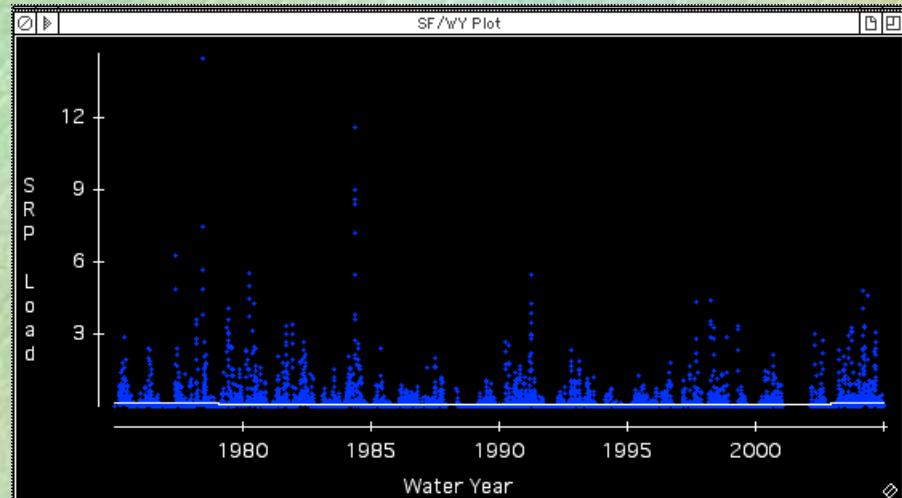


Concentrations

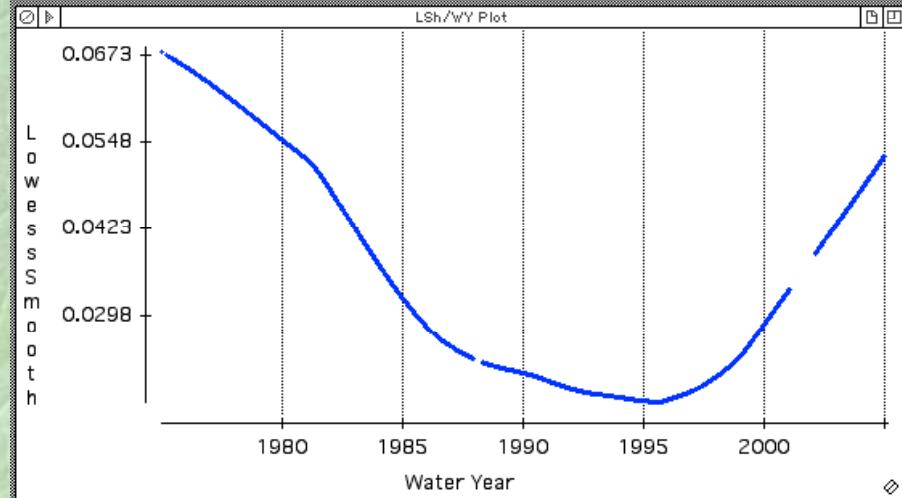
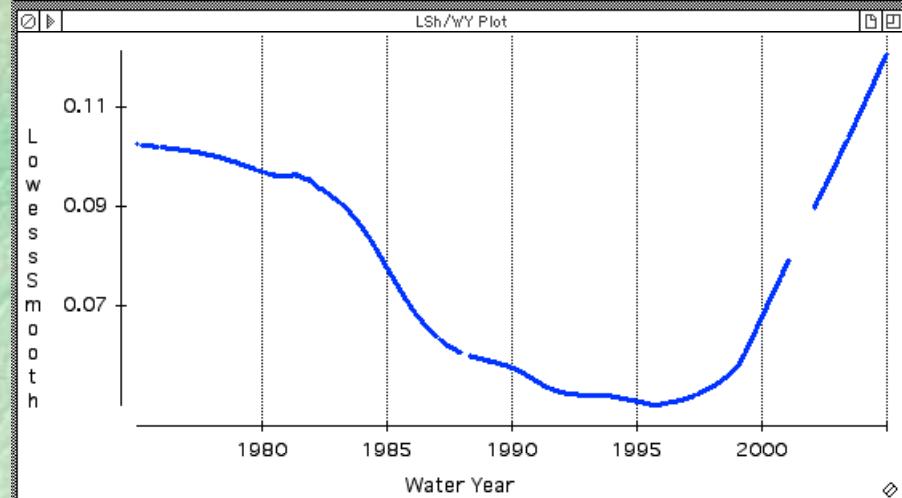
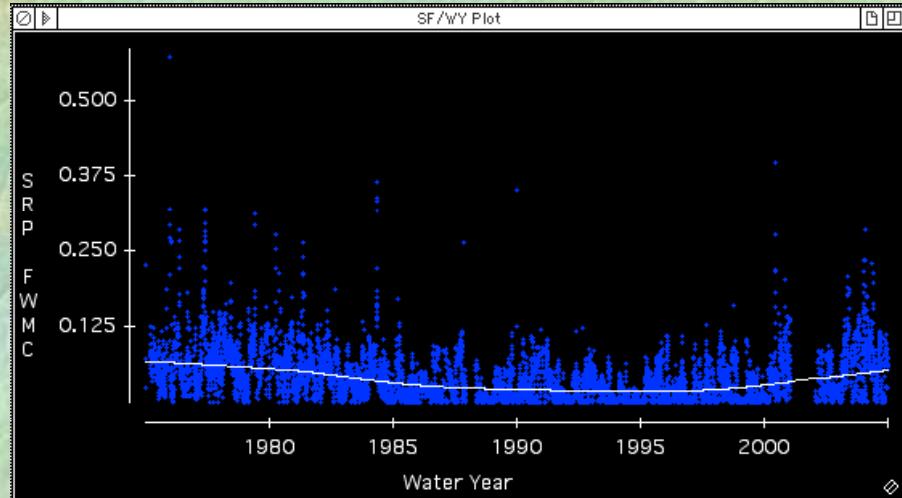


Dissolved Reactive Phosphorus

Loads

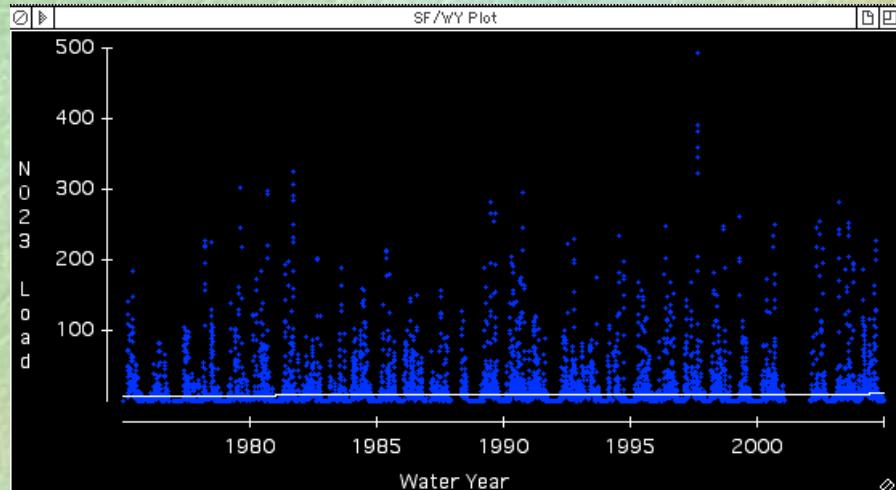


Concentrations

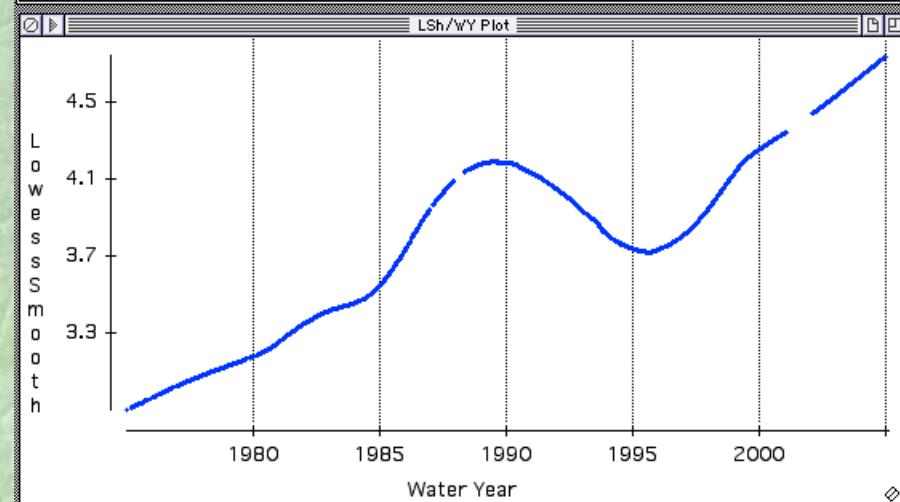
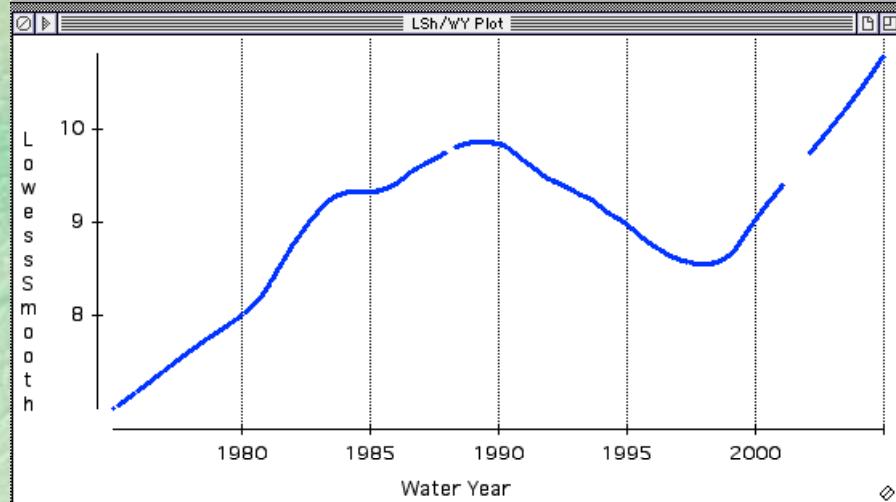
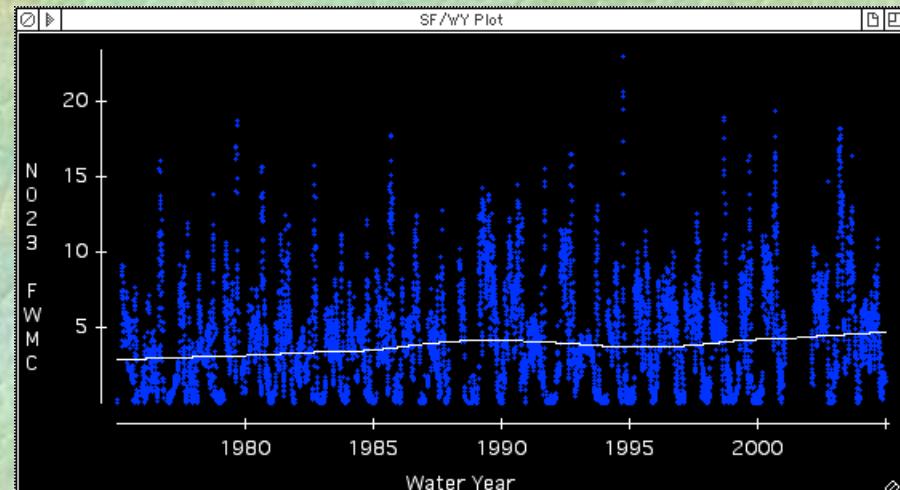


Nitrate

Loads

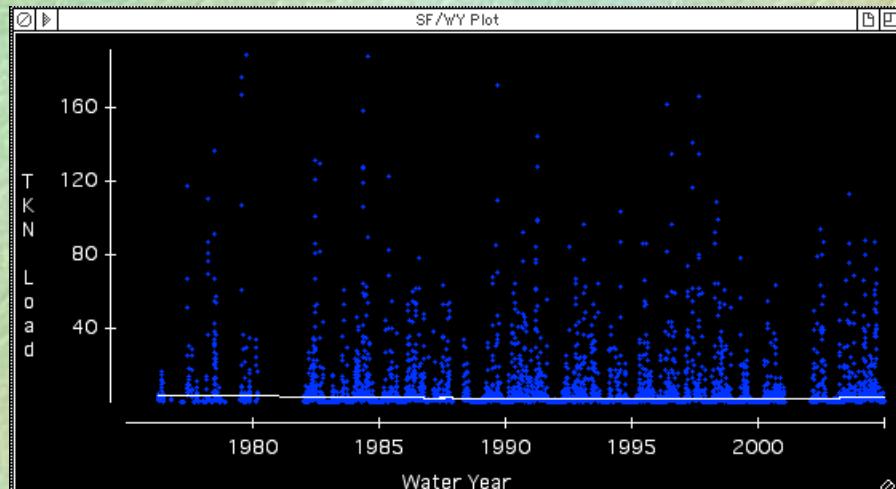


Concentrations

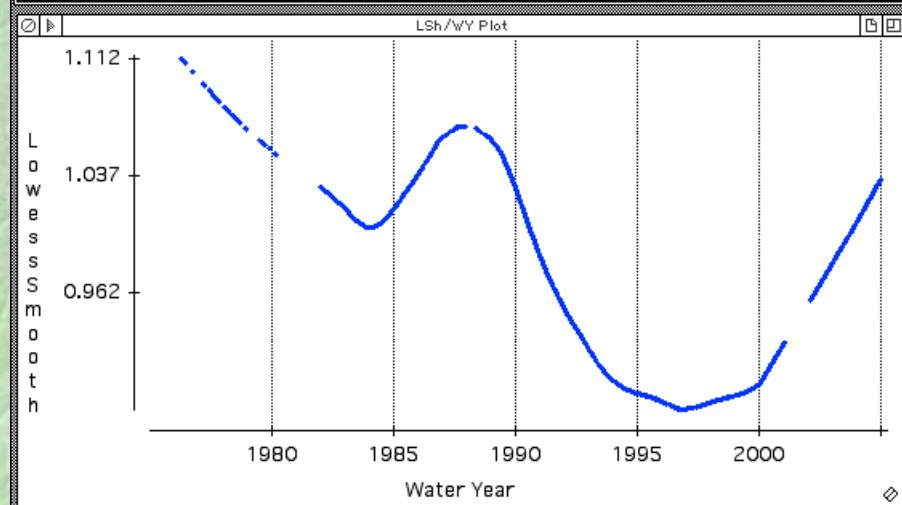
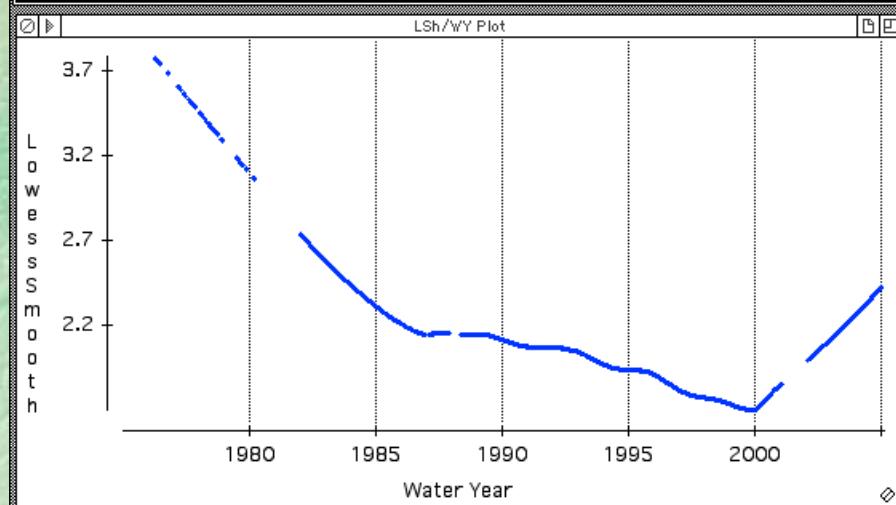
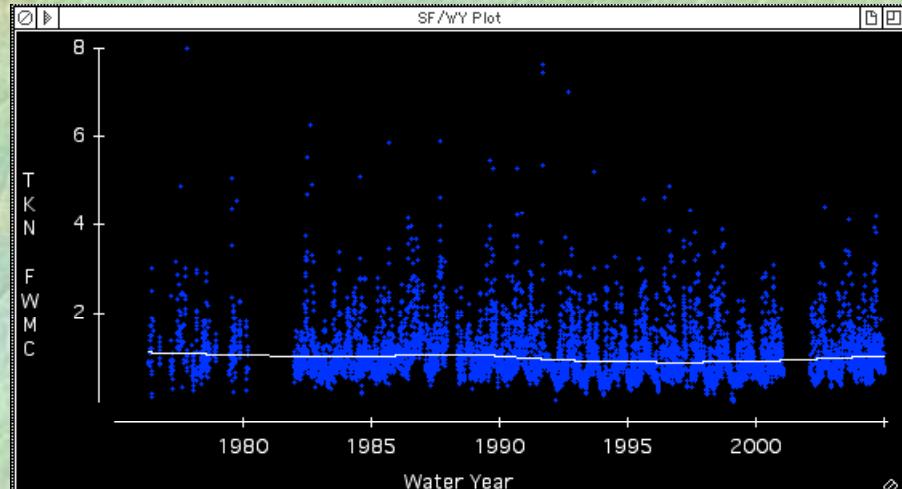


Total Kjeldahl Nitrogen

Loads

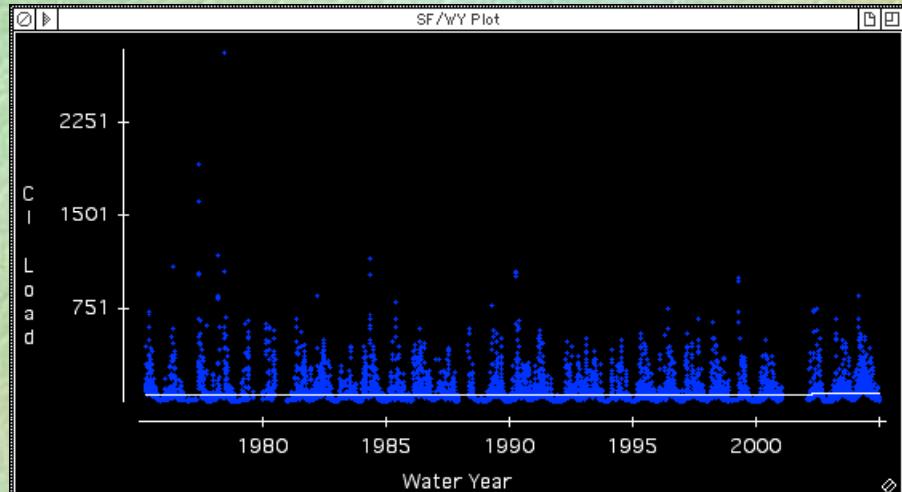


Concentrations

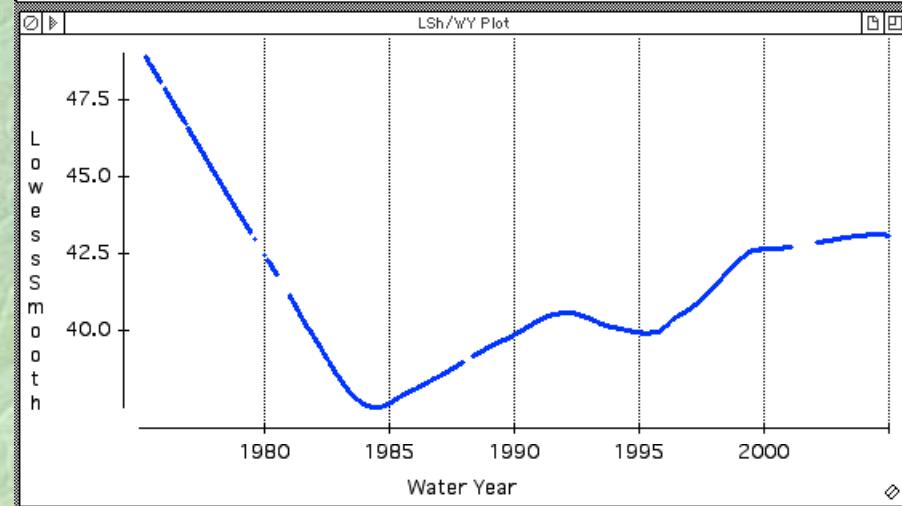
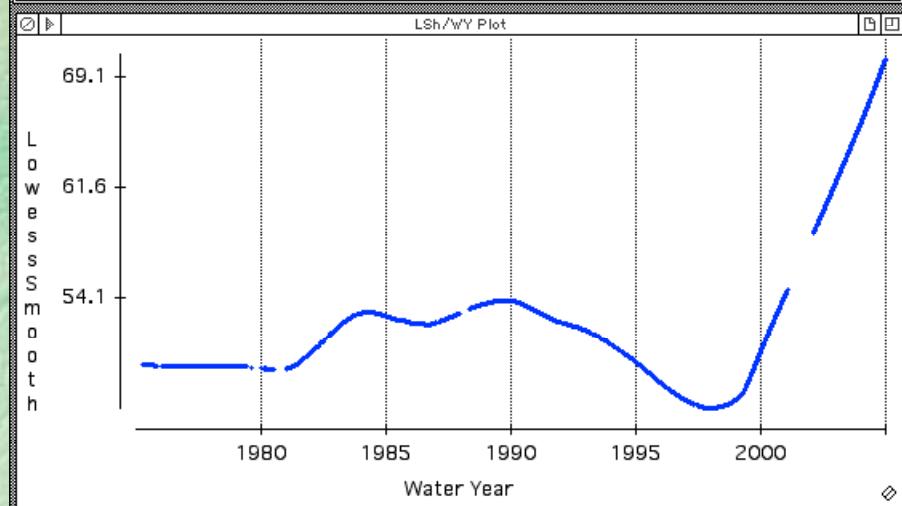
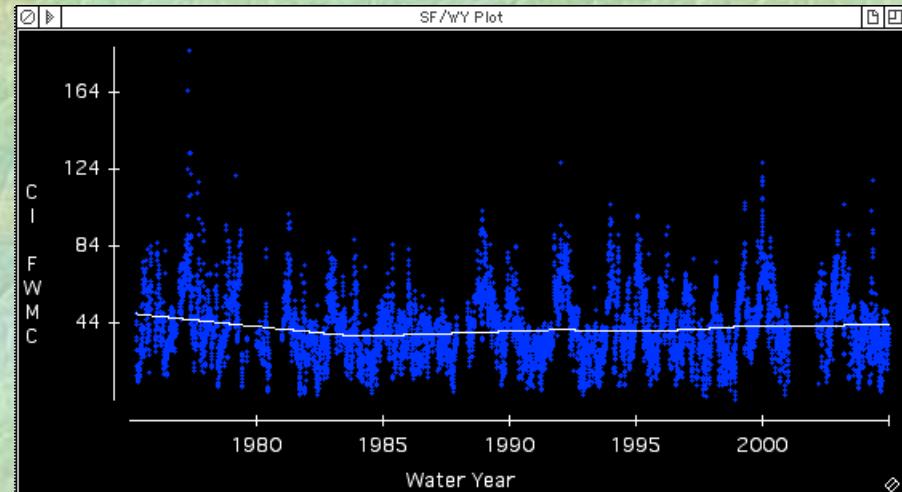


Chloride

Loads



Concentrations



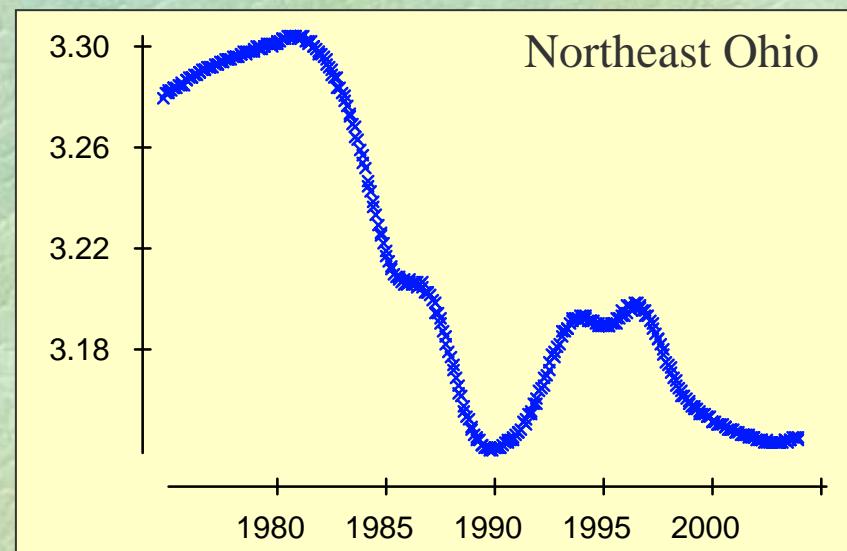
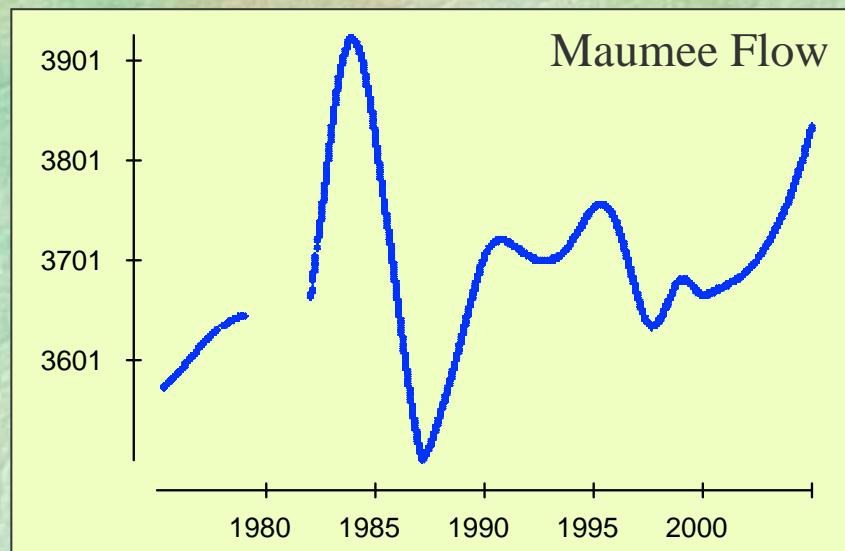
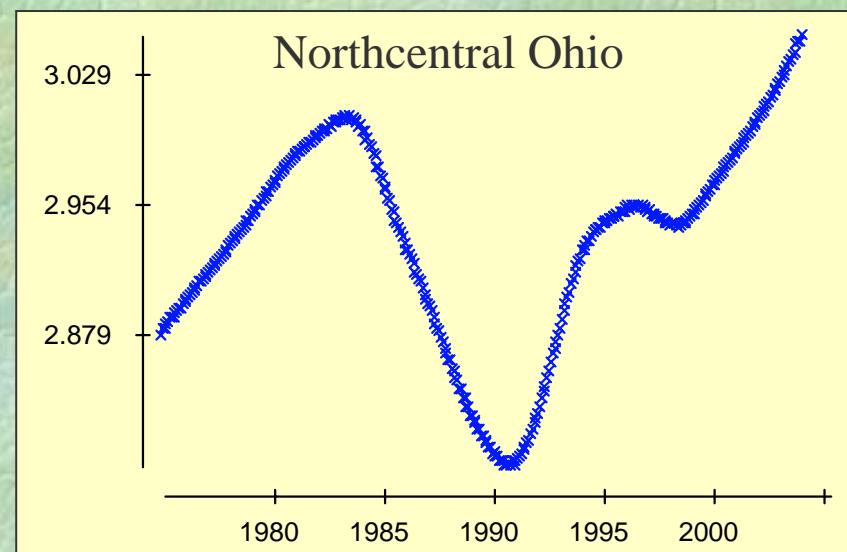
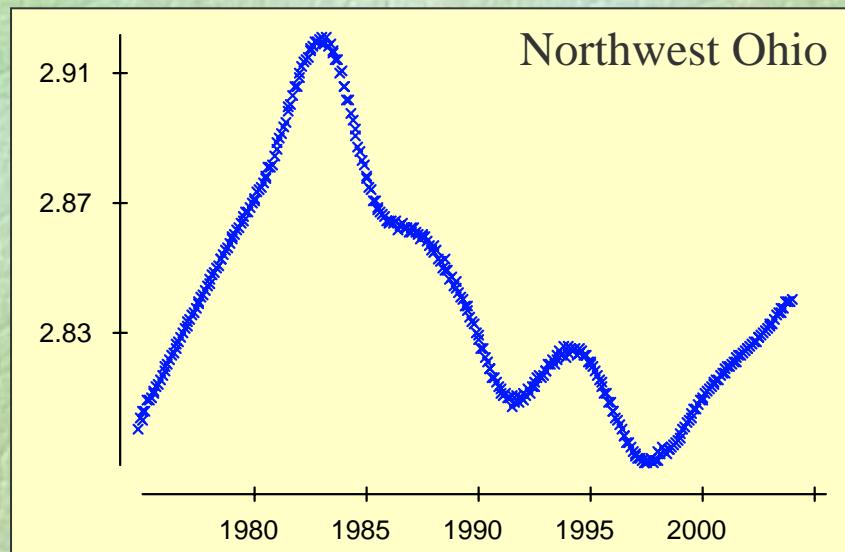
Patterns, Loads vs. Concentrations

- ❖ Loads and concentrations for a given parameter tend to have similar trends
- ❖ But there can be important differences as well
- ❖ SS and TP load trends track flow strongly, others less so or not at all
- ❖ Trends reflect “something real” and important, but...
- ❖ Generally the 30-year trends are small compared to the short-term variability, especially for loads
- ❖ (What does this imply for management?)

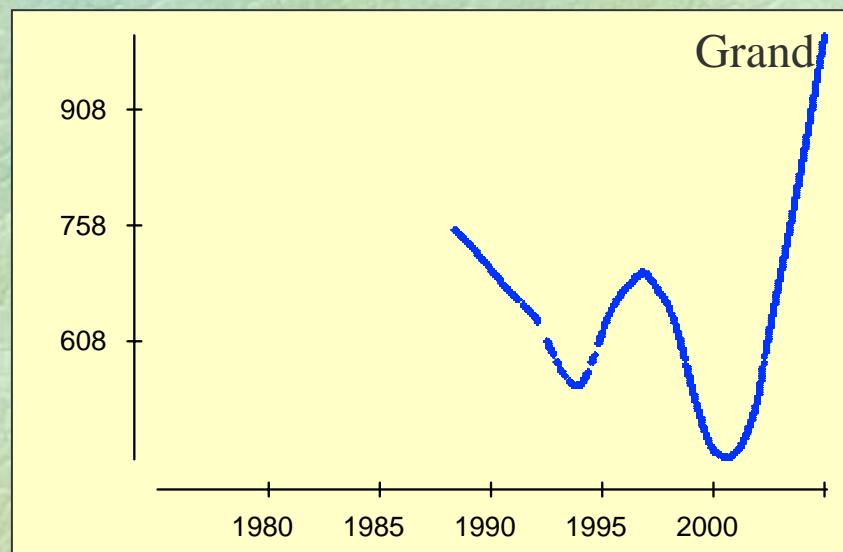
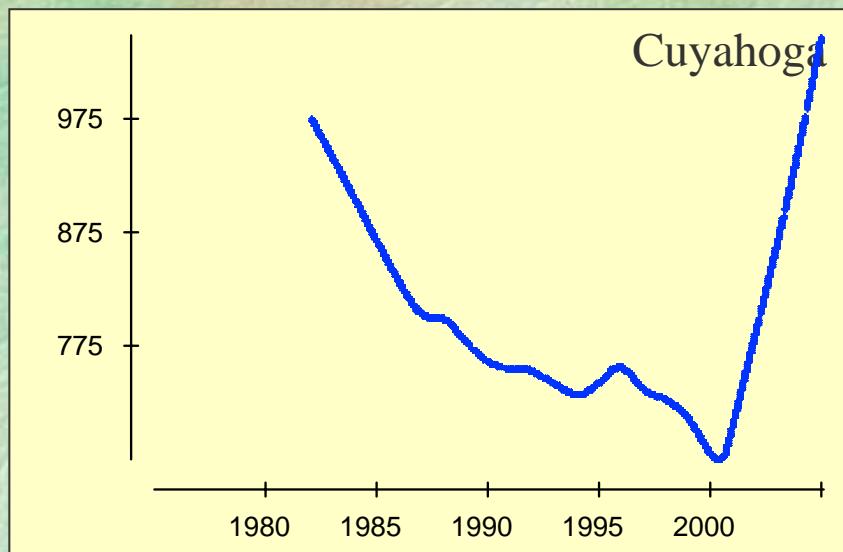
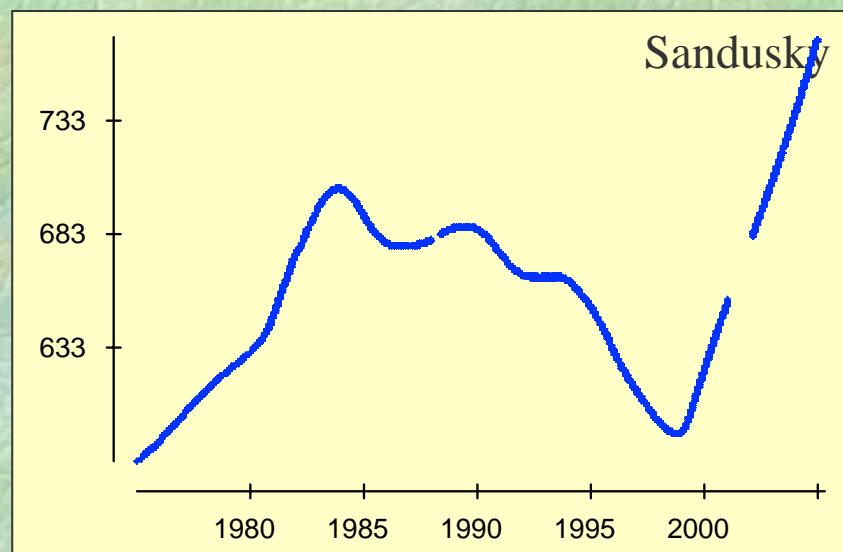
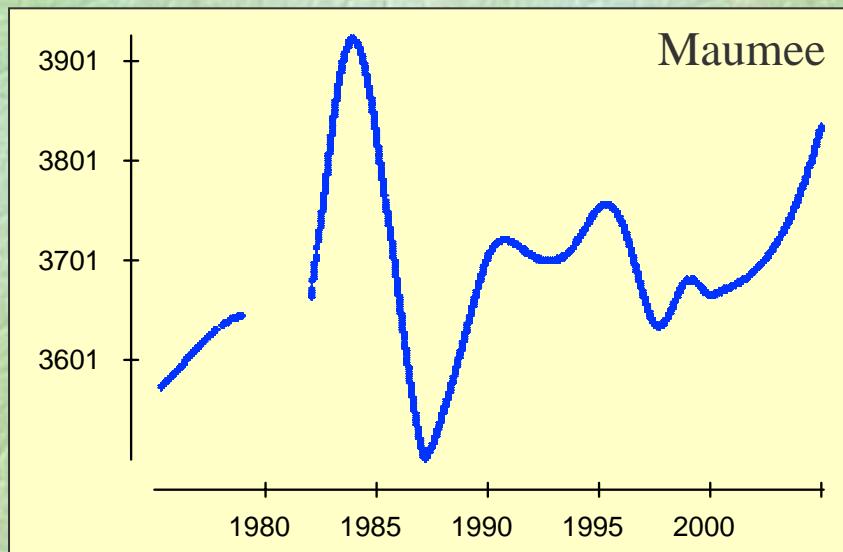
II. Loads, parameter by parameter

- ❖ Flow, SS, nutrients, derivative parameters
- ❖ LOWESS values are essentially locally weighted averages, tend to be intermediate between the median and the mean

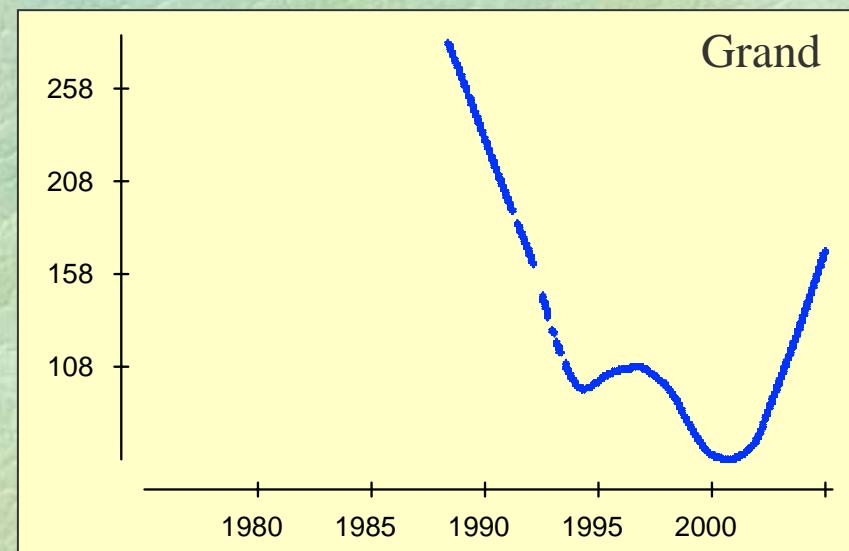
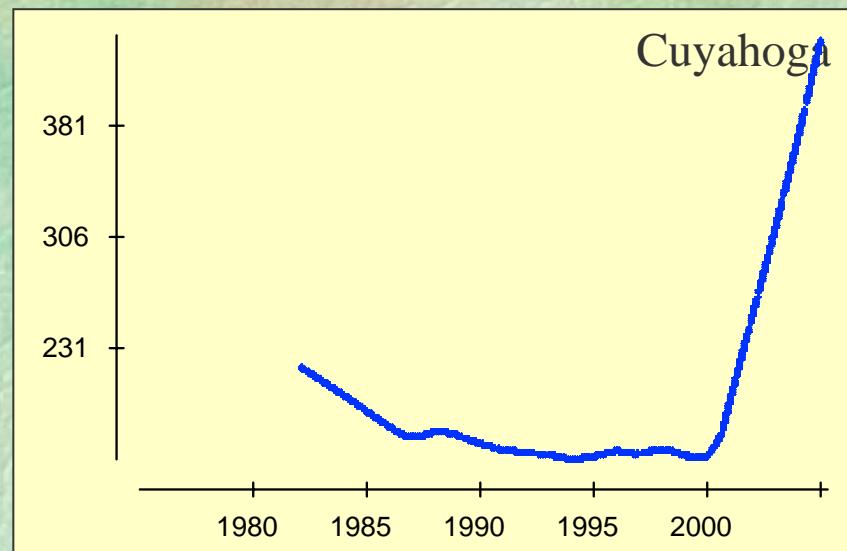
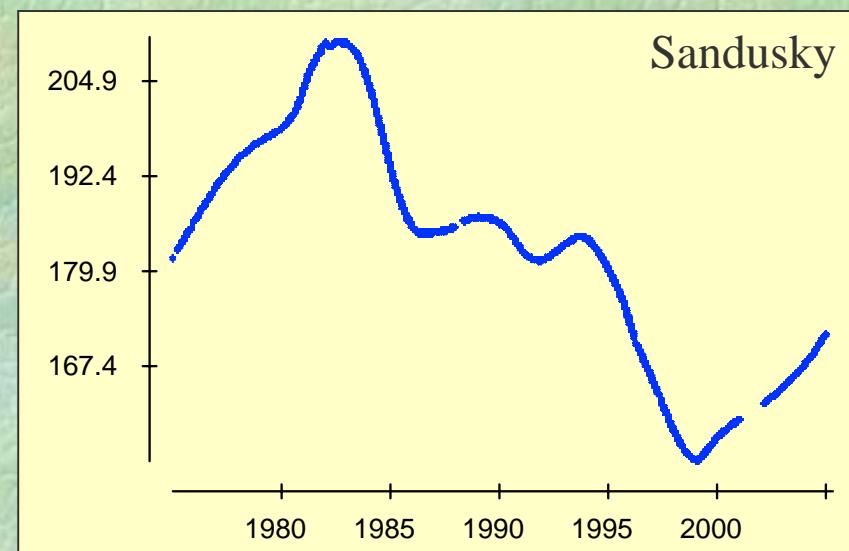
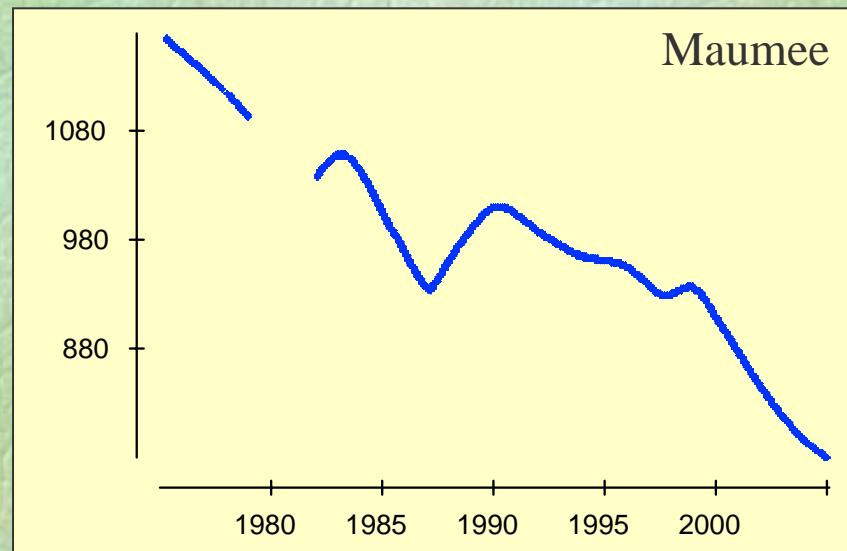
Precipitation (cm/month)



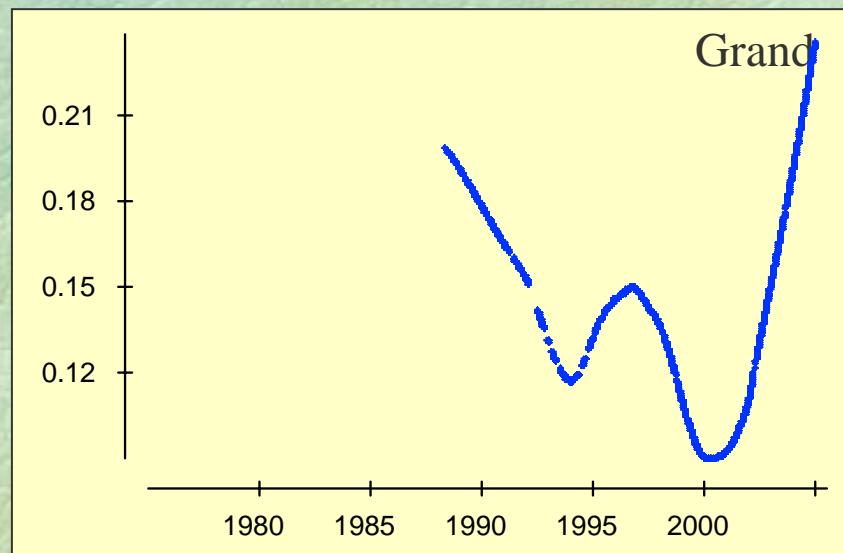
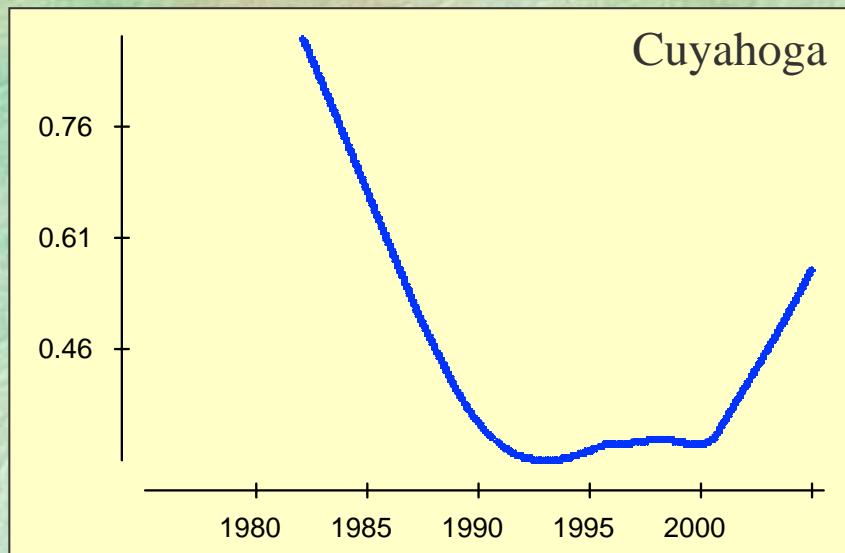
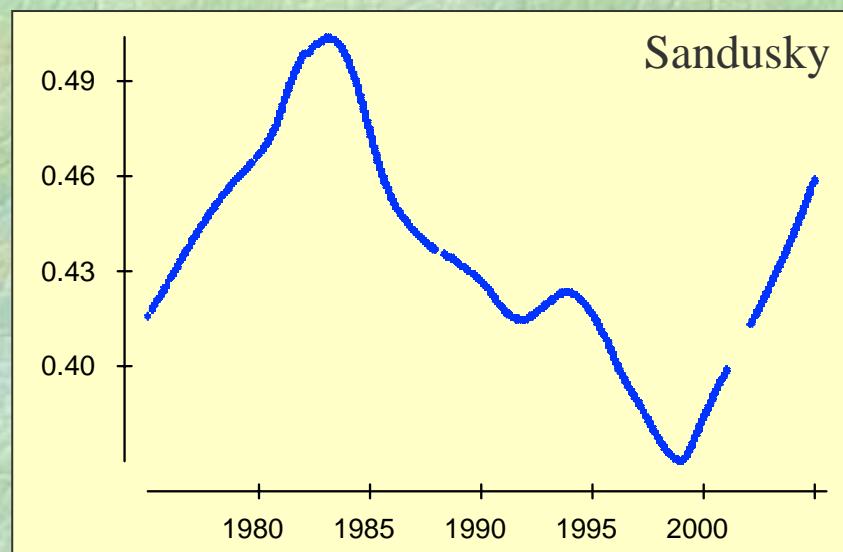
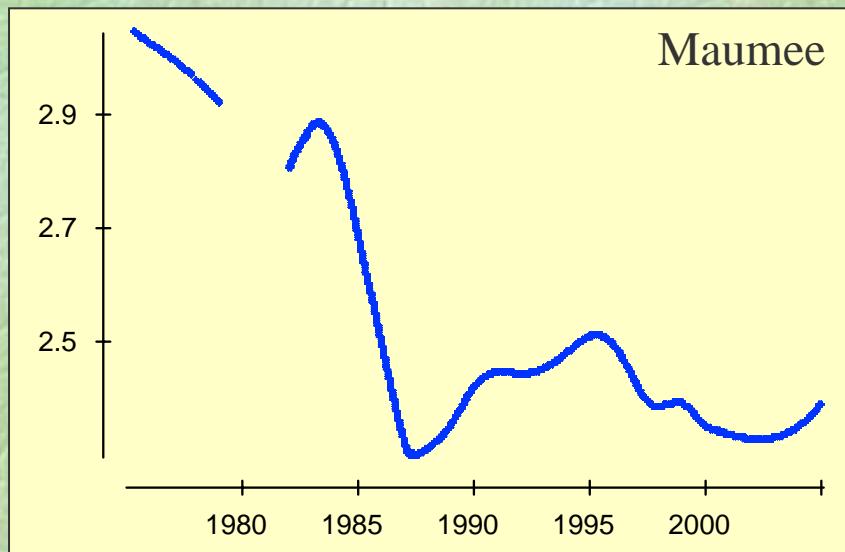
Discharge (cubic feet/second)



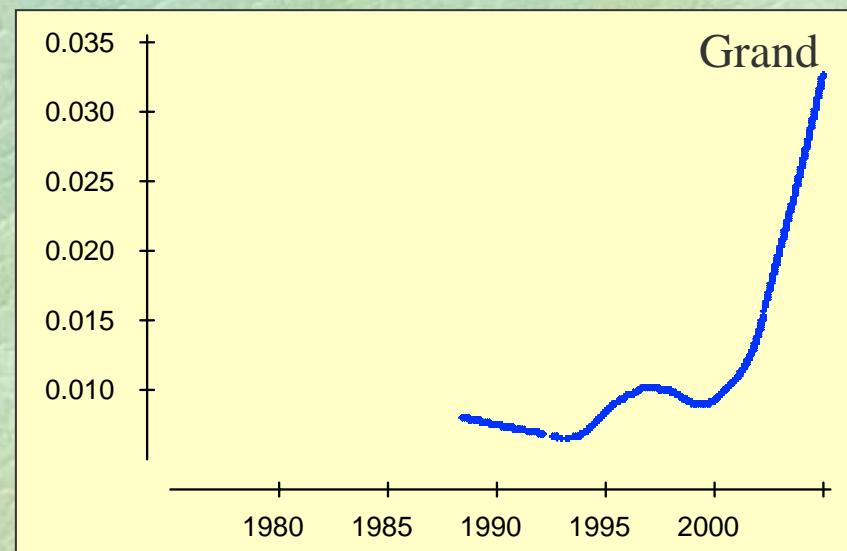
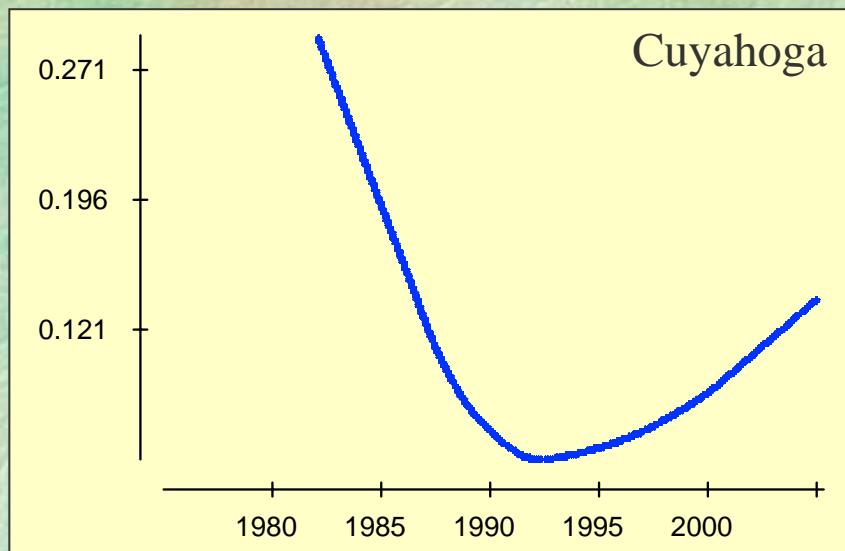
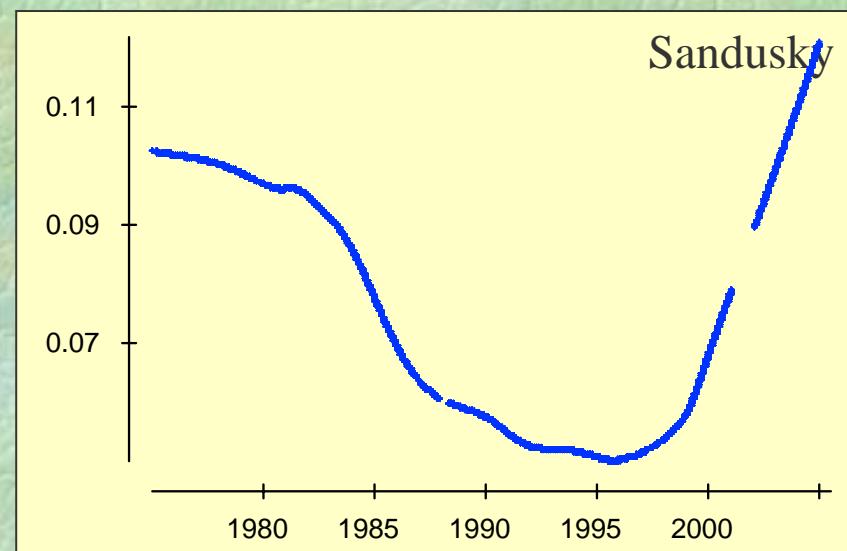
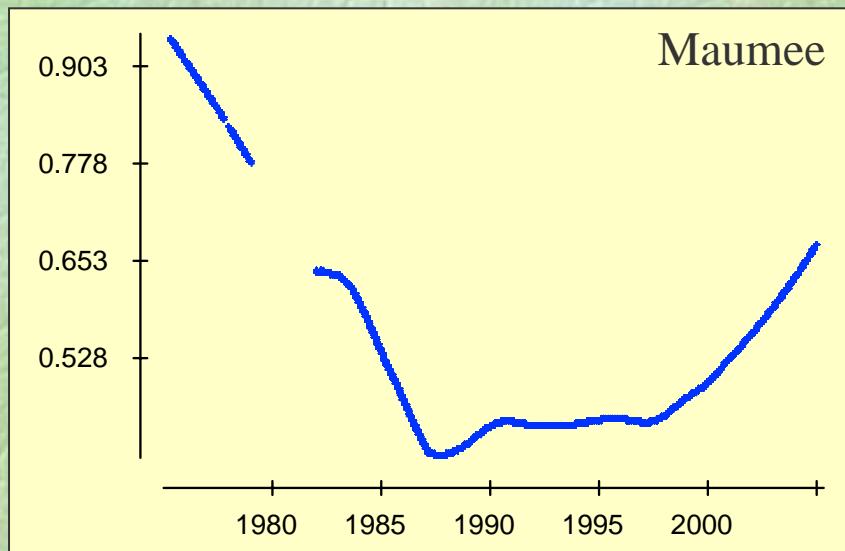
SS Load (metric tons/day)



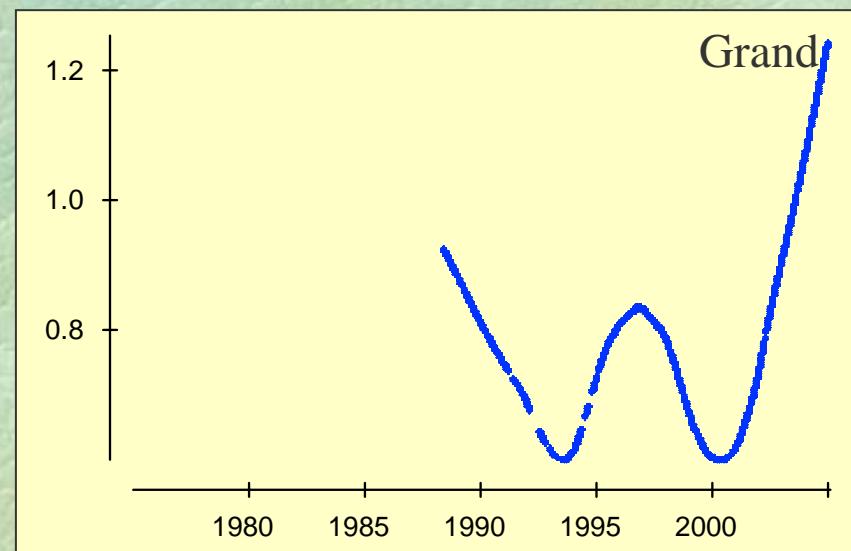
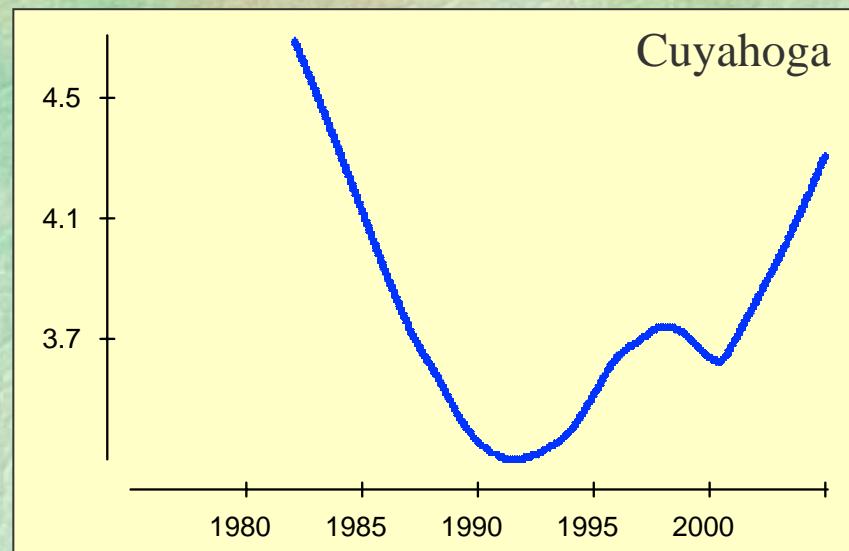
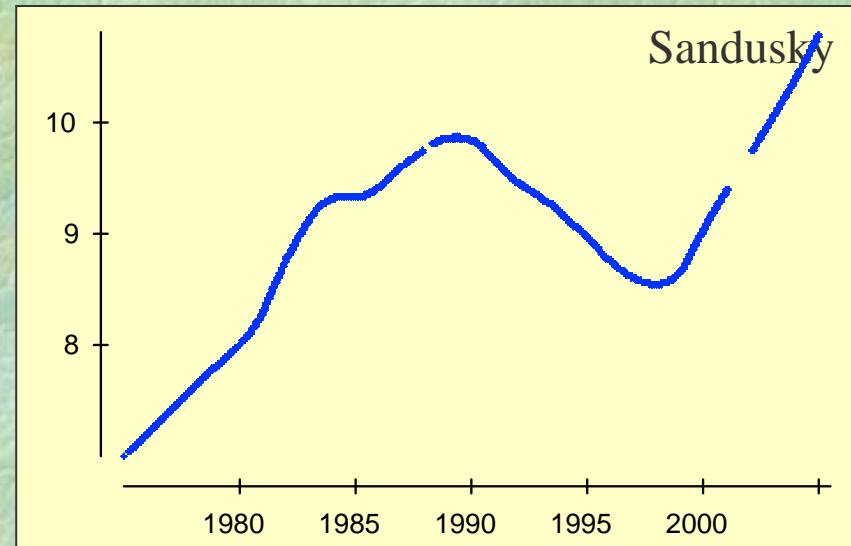
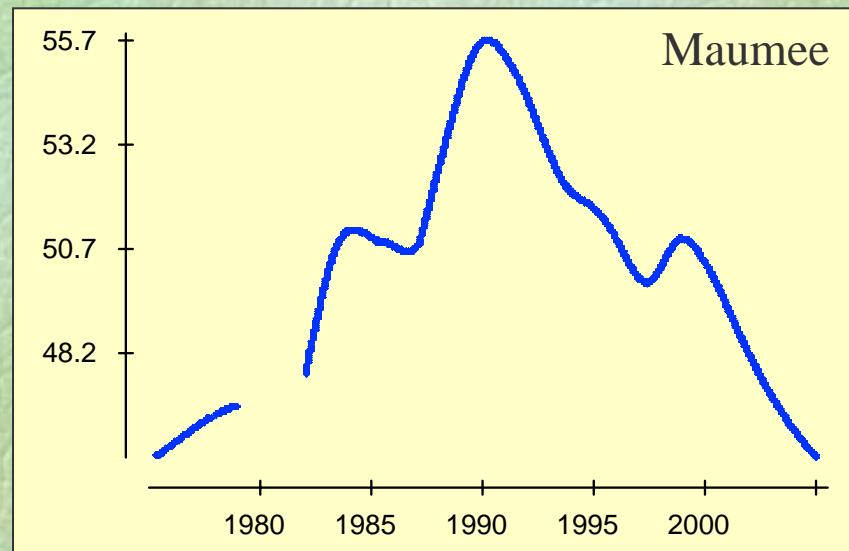
TP Load (metric tons/day)



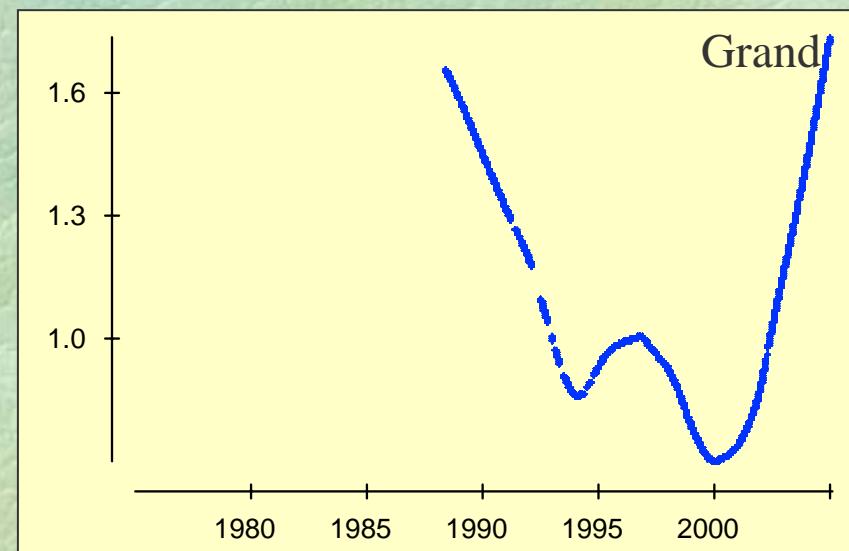
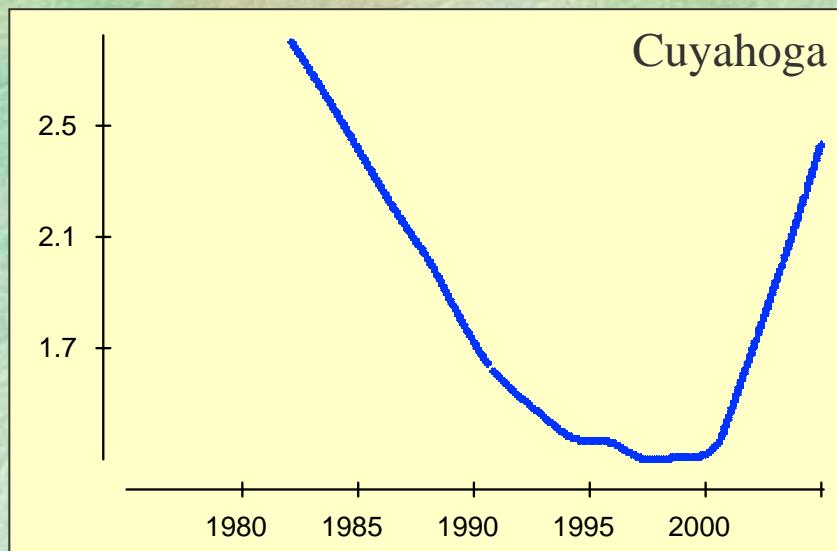
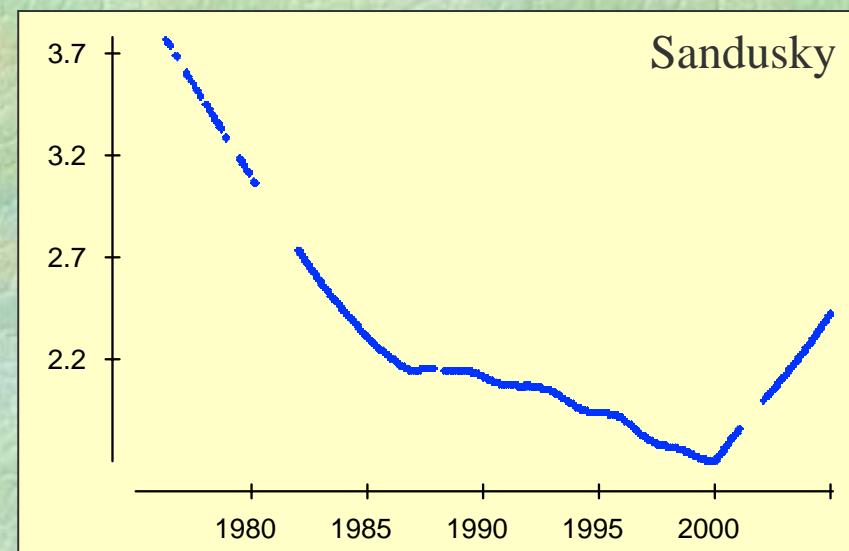
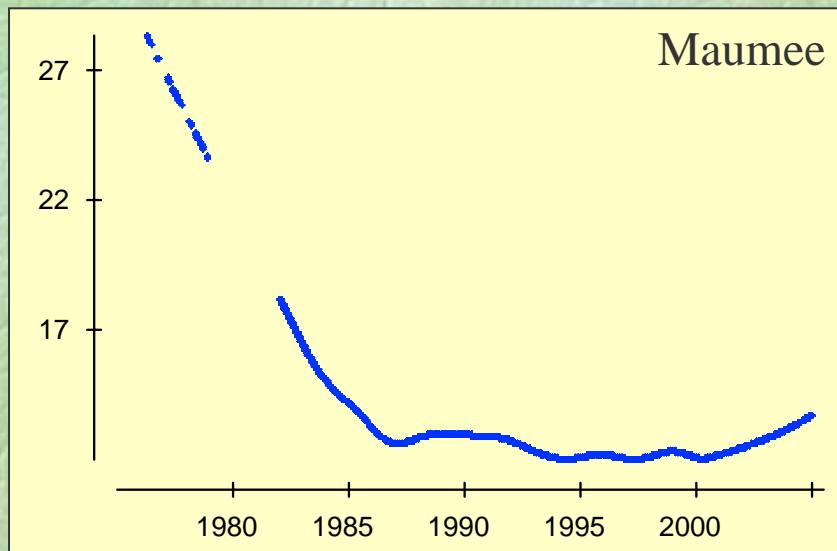
DRP Load (metric tons/day)



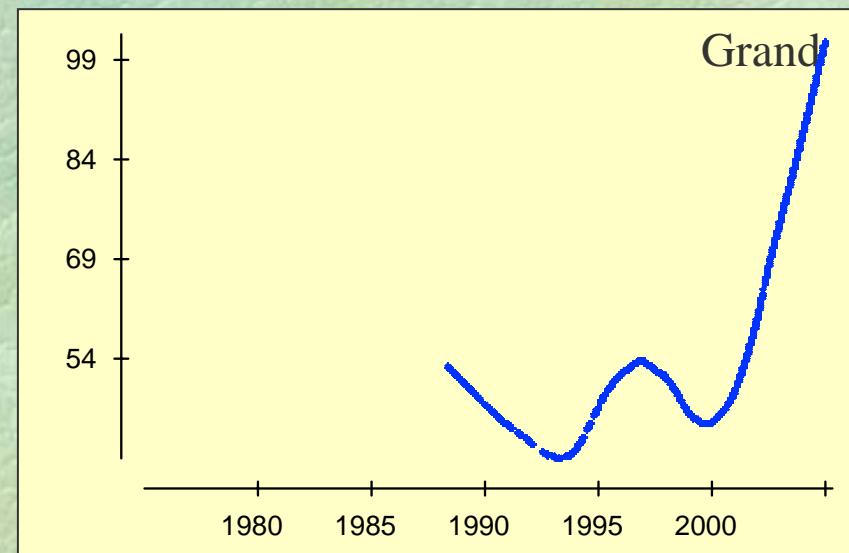
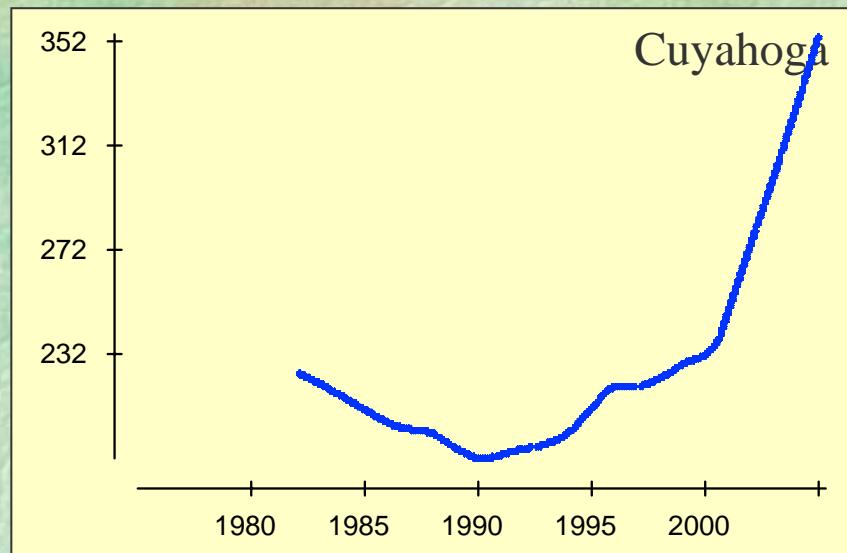
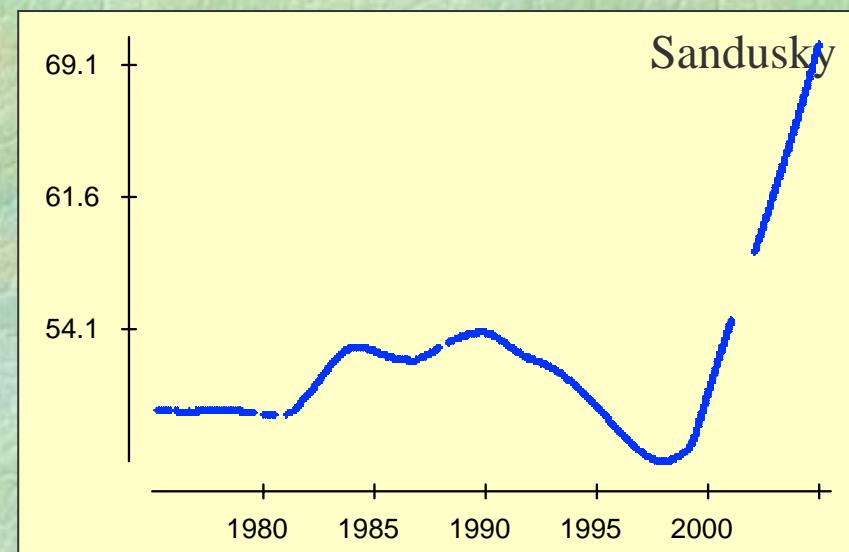
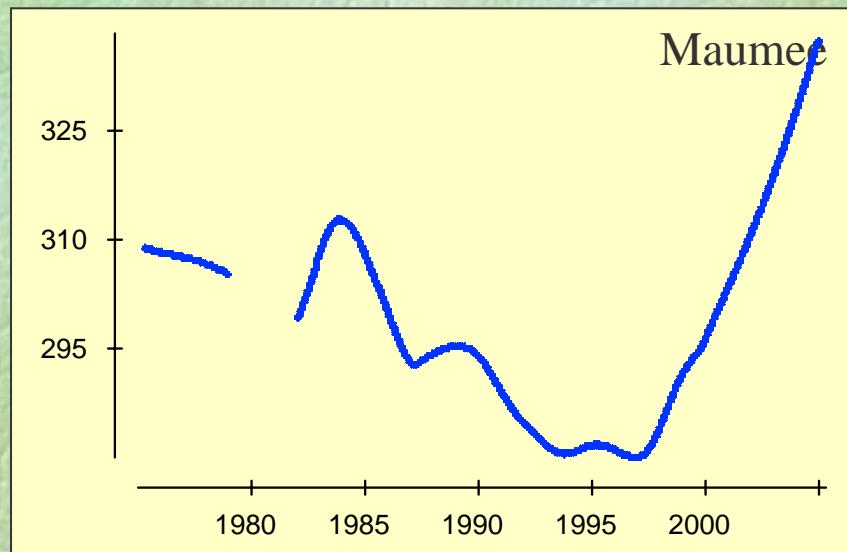
Nitrate Load (metric tons/day)



TKN Load (metric tons/day)

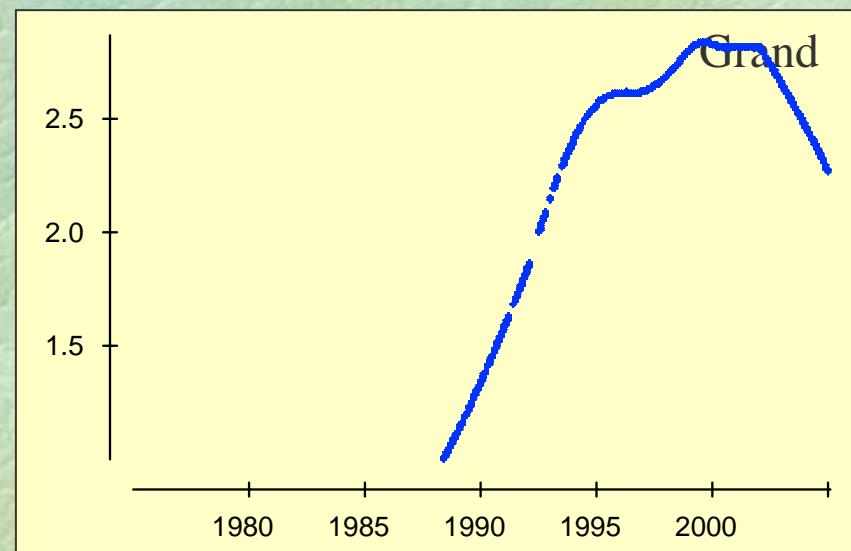
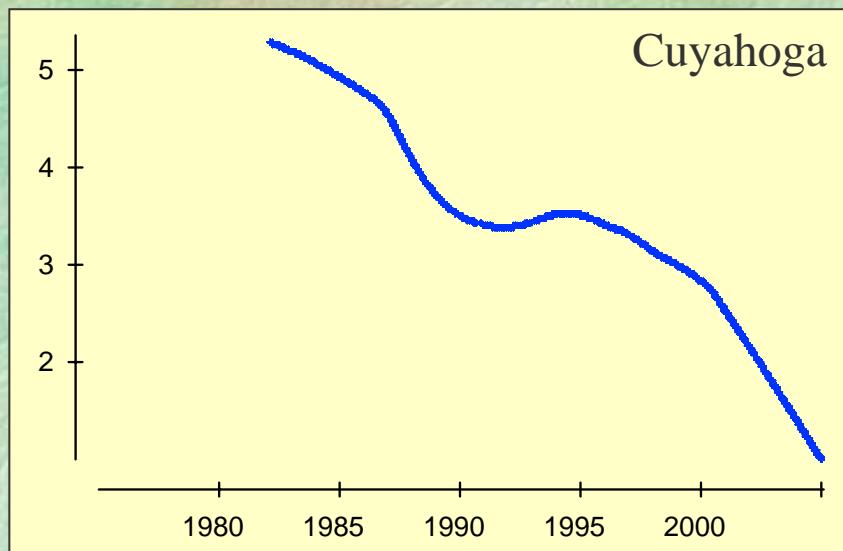
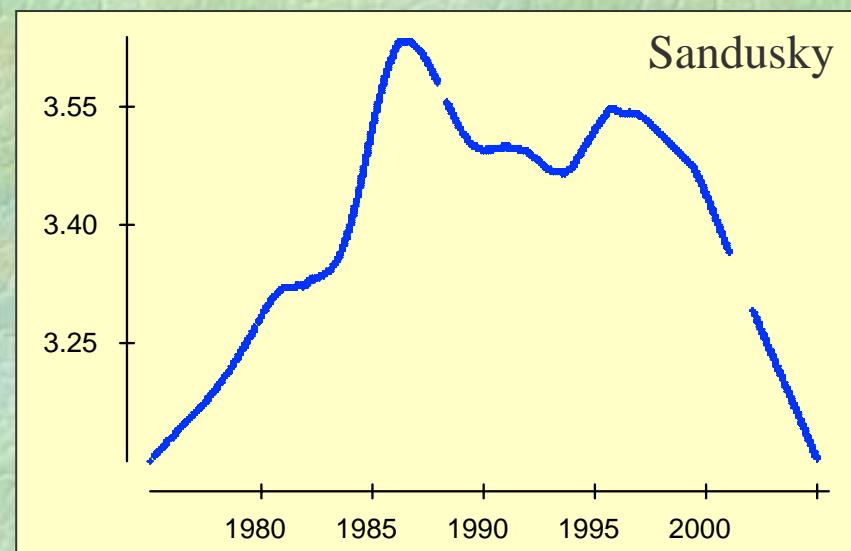
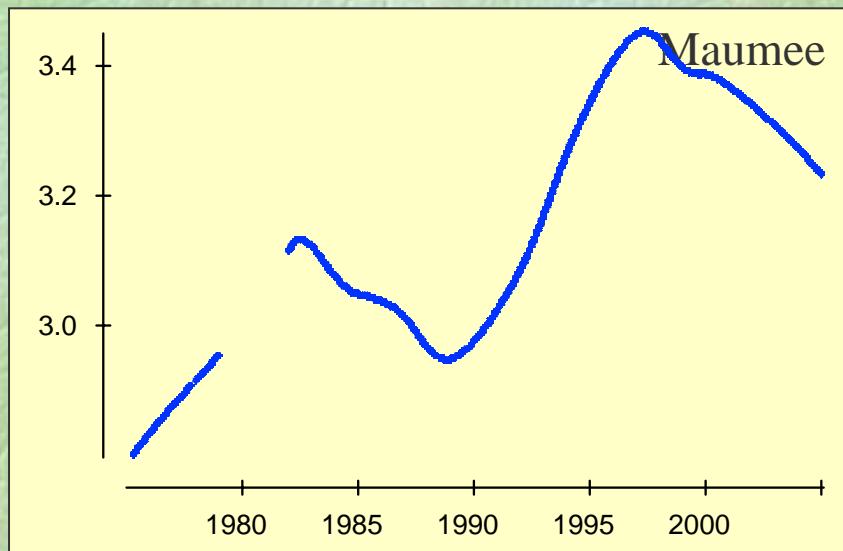


Chloride Load (metric tons/day)

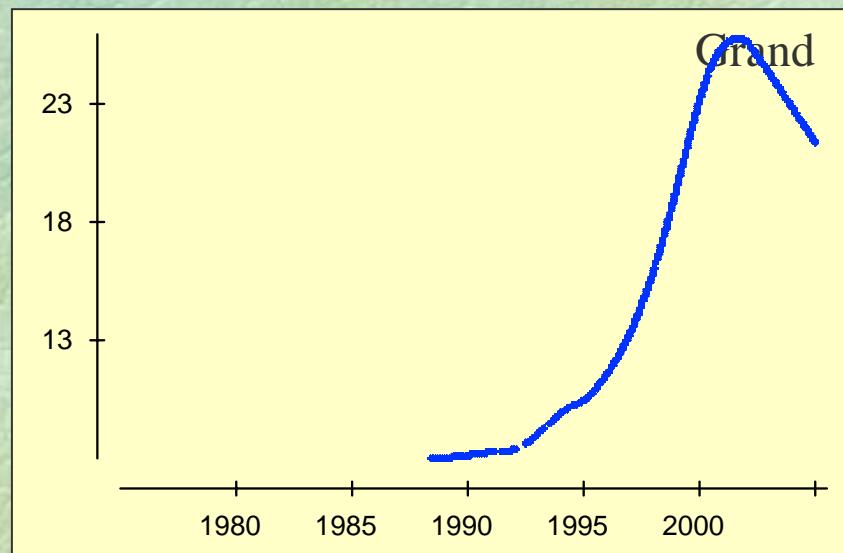
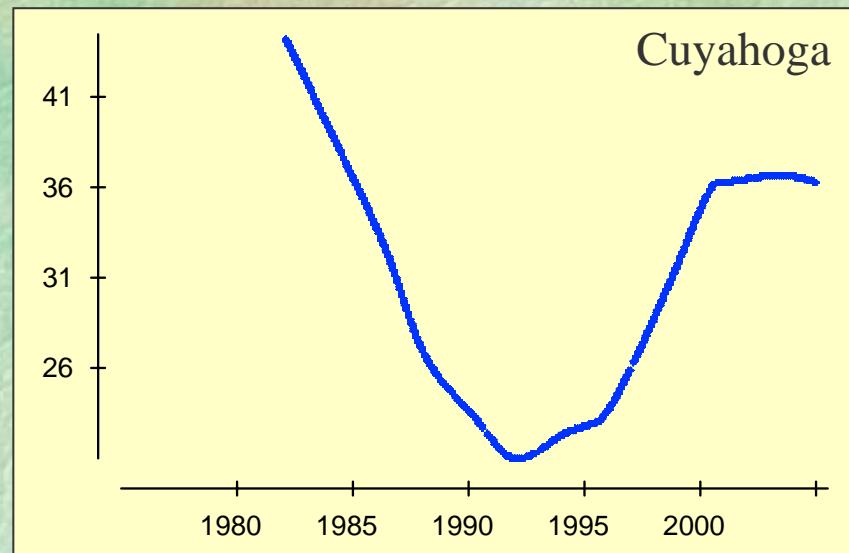
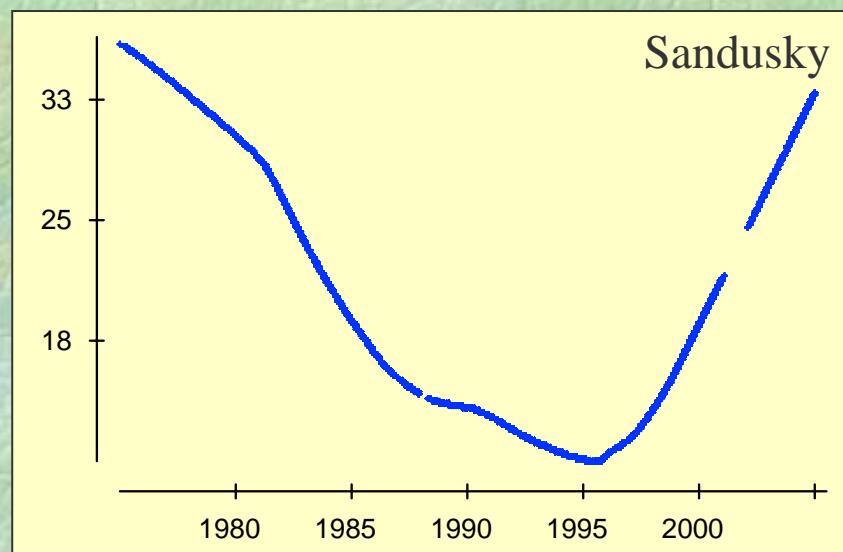
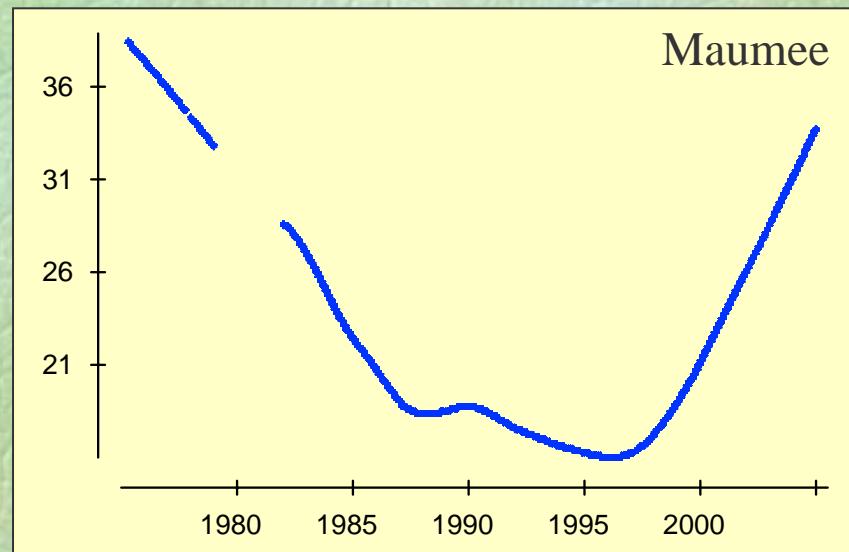


“PP”/SS ratio (g/kg)

(“PP”=TP-DRP)

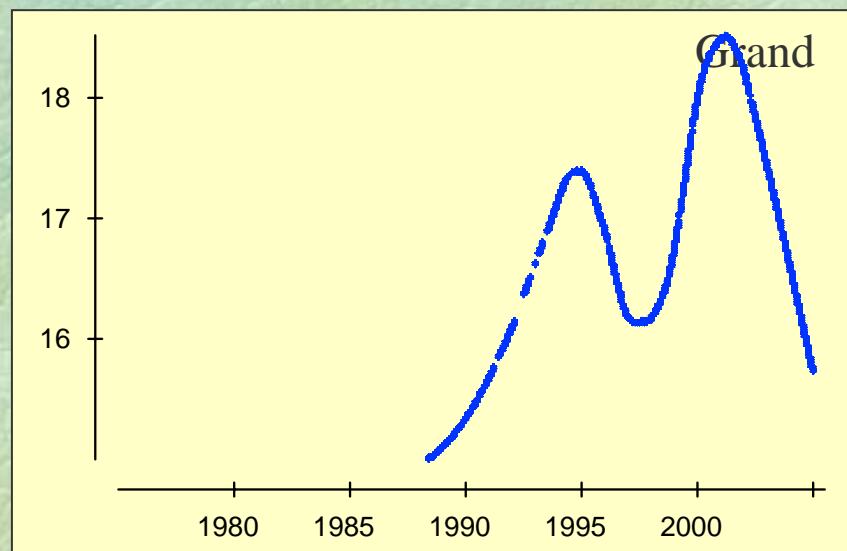
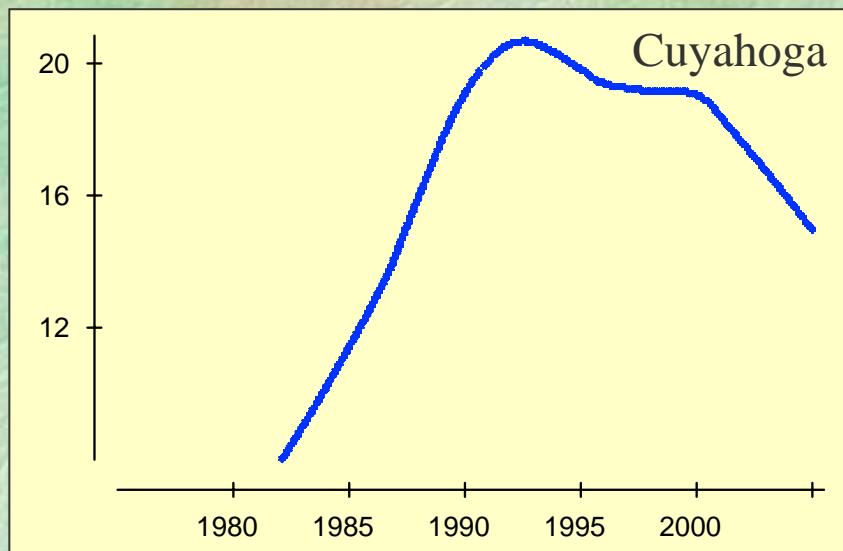
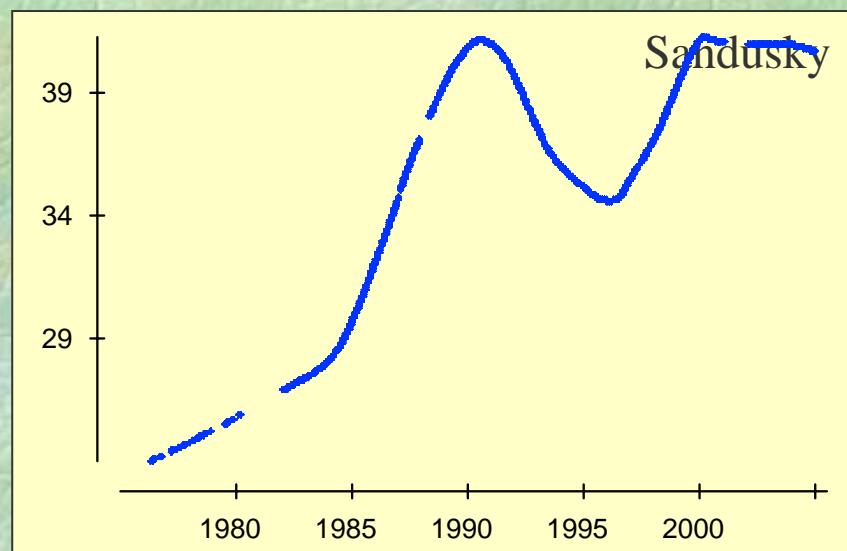
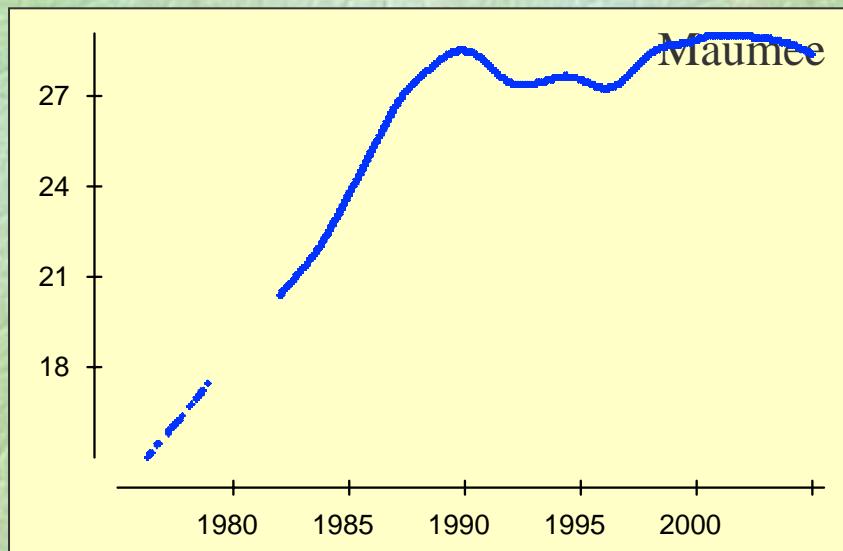


DRP/TP (%)



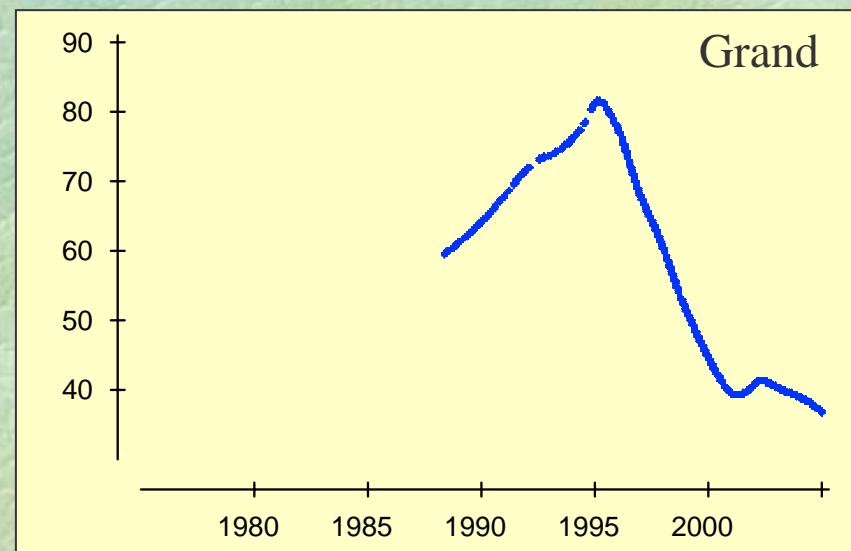
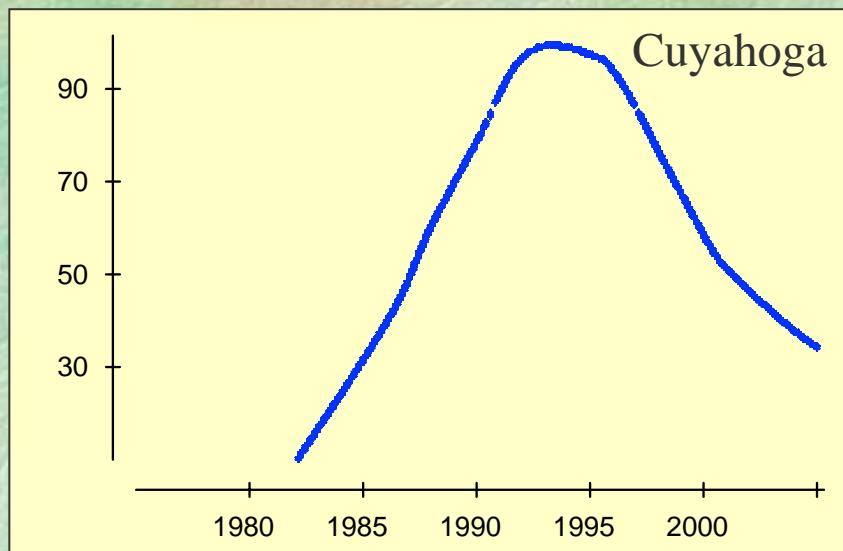
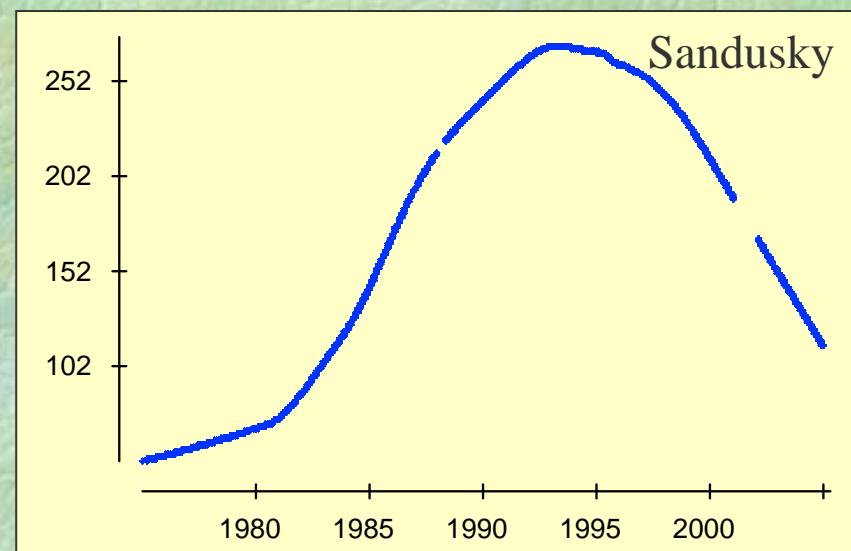
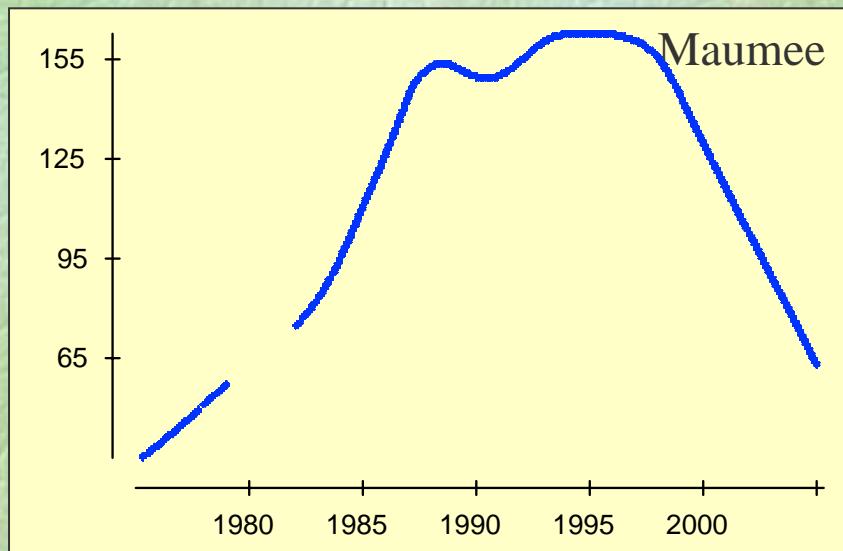
TN/TP ratio

(Redfield Ratio ~ 7)



NO₃/DRP ratio

(Redfield Ratio ~ 7)



Summary

- ❖ General improvements (except nitrate) during 1975-1995, most params/most rivers
- ❖ Worsening in TP, DRP, TKN since then; inflection point between 1993 and 2000
- ❖ Continued improvement in Maumee SS but not in other rivers
- ❖ Mixed results for NO₃

Summary

- ❖ PP/SS ratio (sediment “richness”) improving recently, but perhaps for bad reasons
- ❖ Recent increases in %P that is dissolved
- ❖ TN/TP and NO₃/DRP decreasing or no longer increasing, but ratios are appropriate for phosphorus limitation

Causes?

- ❖ Weather? More important for loads than concs?
- ❖ Population growth and exurbanization?
- ❖ No-till concentrates nutrients at surface?
- ❖ Concentrated animal agriculture?
- ❖ Winter spreading of manures?
- ❖ Global climate change?
- ❖ Whew! It could be all of them....

Impacts?

❖ Renewed problems in Lake Erie

- Increased in-lake phosphorus concentrations
- Hypoxia in summer in Central Basin
- Microcystis and other cyanobacteria

❖ Tributary inputs are not the sole cause, but are likely contributors to these problems



THE END